



## Incubator for Joper Day Old Chicks with Cohen-Coon PID Controller

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### A B S T R A C T

Joper (Jowo Super) chicken parents are generally unable to incubate eggs or provide adequate care for their offspring, making the use of a specialized incubator essential from the hatching phase to Day-Old Chick (DOC) rearing. One of the primary factors contributing to DOC mortality is improper temperature adjustment in the heating system. To ensure optimal early-age development, Joper DOC requires a stable thermal environment within the range of 32°C to 35°C, depending on the growth stage. This study aims to develop an incubator capable of maintaining a constant temperature of 32 °C using Cohen-Coon PID (C-C PID) control while also regulating humidity levels. The proposed incubator integrates an axial fan and an L298N driver, with the temperature and humidity sensors calibrated prior to use. The calibration results show measurement errors of 0.59% for temperature and 5.02% for humidity, indicating high reliability. The application of C-C PID control demonstrates strong performance, characterized by a short rise time (approximately 225 seconds), an acceptable settling time (around 510 seconds), minimal overshoot (1.56%), and a steady-state error approaching 0%. During a 30-minute evaluation period, the system successfully maintained a stable temperature at the 32 °C set point and controlled humidity at below 50% automatically. Furthermore, the incubator design proved effective in practical use, achieving a 0% mortality rate for Joper DOC.

### INTRODUCTION

Joper chickens are the result of crossbreeding between male kampong chickens and female laying hens [1]. The development of genetic varieties of Joper chickens is due to market demand for kampong chicken meat, but the growth of kampong chickens tends to be slow [2]. Joper chicken has many advantages, such as they can be produced in large quantities with uniform weight, the growth rate is faster than native chickens, they have a low mortality rate, are easy to adapt to the environment, and have the same taste as free-range chicken [3].

DOC (Day Old Chick) is a chicken aged 1 – 14 days after the egg hatches. In the animal husbandry sector, chicks that have only been hatched for up to 14 days must be intensively cared for by breeders. If care is lacking, the DOC will die, and breeders will experience big losses. One of the key considerations in DOC care is regulating the temperature of the coop. Coop temperatures that do not match DOC requirements will cause death [4][5].

Hatched DOC aged 1 – 7 days requires cage temperatures between 28°C and 33°C [6][7][8][9], with humidity levels of 30% to 50% [10][11]. To maintain the coop room temperature, breeders must check it regularly. Therefore, a special incubator is required that can automatically regulate temperature and humidity. To do this, a proper control method is required.

One of the recommended methods is a PID controller. The popularity of PID control is related to its good performance and functional simplicity. A three-mode controller contains proportional (P), integral (I), and derivative (D) terms to make the system produce the desired response [12][13]. An engineer can efficiently obtain these response results through testing or some simple principles, such as the classical tuning rules proposed by Ziegler-Nichols (Z-N), or more complex ones using Cohen-Coon (C-C) [14].

PID is highly flexible for use in various sectors because each control parameter plays a crucial role in shaping the system response. Proportional control parameters have the advantage of a fast rise time and reduced steady-state error, integral control parameters have the advantage of reducing steady-state error, and derivative control parameters have the advantage of reducing overshoot [15][16].

The flexibility of PID control makes it applicable in various areas of control. For example, research on PID control is used to regulate the movement of firefighting robots [17]. Other research uses PID control to regulate thermal variables in pig farming areas [18], to control autopilot airplanes [19], and to control motors for various purposes [20][21][22].

Based on several references presented, PID control is an appropriate method for controlling the temperature of the Joper DOC incubator. However, this research will focus solely on

automatic temperature control using a PID controller with the Cohen-Coon tuning method (C-C PID), based on the First Order Plus Dead Time (FOPDT) model. Meanwhile, to control humidity, the DOC incubator is equipped with an axial fan and an L298N driver without involving C-C PID.

The importance of DOC care methods to avoid the risk of death and economic losses caused, encourages researchers to design an incubator based on Cohen Coon (C-C) PID tuning control to reduce the mortality rate of Joper DOC. This research will focus on maintaining stable and even temperatures by utilizing a C-C PID controller, aiming to minimize the mortality rate as much as possible. In addition, this research is also expected to contribute significantly to the advancement of joper chicken farming in Indonesia.

**METHODS**

**Electrical Design and Mechanical Design**

The electrical design of the Joper DOC incubator is planned as shown in Figure 1. Several components are used, including a special incubator lamp, an axial fan, a DHT22 sensor, an L298N driver, and an AC light dimmer module, all of which are controlled by an Arduino Nano microcontroller.

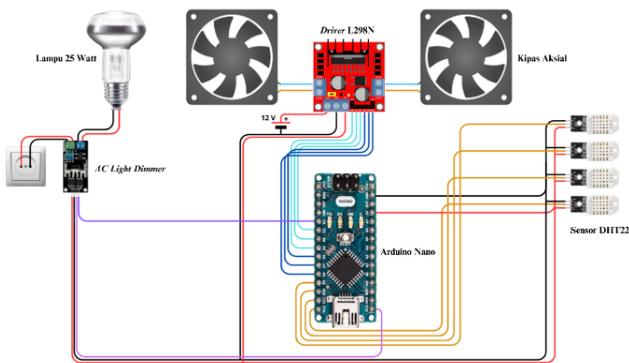


Figure 1. Electrical Design of DOC Incubator

Based on this figure, the electrical circuit works can be described as follows: 1. The DHT22 sensor will continuously send temperature and humidity to the Arduino Nano microcontroller; 2. The microcontroller that receives temperature data will send commands to the AC light dimmer to control the lamp's light intensity 3. Meanwhile, the L298N driver will be used to regulate the fan based on humidity input.

The mechanical design of the incubator is illustrated in Figure 2. The incubator consists of three parts that serve different functions. The top of the incubator, measuring 60 cm x 60 cm x 20 cm, serves as a housing area for the controller and several other electrical components. The middle or main part, measuring 60 cm x 60 cm x 60 cm, functions as a maintenance area for DOC Joper. This section will control temperature and humidity according to the previous planning. Meanwhile, the lower part, measuring 15 cm x 60 cm x 60 cm, is used solely for supporting and placing the Joper DOC manure. The main part of the incubator's mechanical design is constructed using 10 mm thick plywood. Then, on the front, acrylic is added, measuring 40 cm x 40 cm and with a thickness of 3 mm. Acrylic is used to monitor the condition of the DOC in the incubator more easily.



Figure 2. Mechanical Design of DOC Incubator

**The Model of PID Controller**

The PID controller algorithm combines the actions of three parameters based on feedback signals as in Figure 3. The controller attempts to bring the measured output to the desired value by minimizing errors in the feedback. In the process, the system will adjust the process input or manipulated variables. The general form of the equation for the manipulated variable in the time domain (MV(t)) is as follows:

$$MV(t) = K_p e(t) + K_i \int_0^t e(t)dt + K_d \frac{d}{dt} e(t) \tag{1}$$

In equation (1), values of Kp, Ki, and Kd are the controller gain (P), integral gain (I), and derivative gain (D). Parameter P depends on the current error, parameter I represents the accumulation of past errors, and parameter D predicts future errors. These parameters affect the process if Kp and Ki are too high, resulting in high offset and overshoot, while Kd can reduce the overshoot caused by Ki [23].

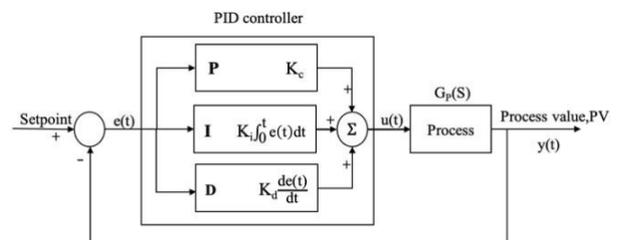


Figure 3. General Model of PID Control

To get the values of Kp, Ki, and Kd in the general model, tuning must first be done with an open loop or this process is usually called step input. The response from the input step will produce an S-shaped curve as shown in Figure 4.

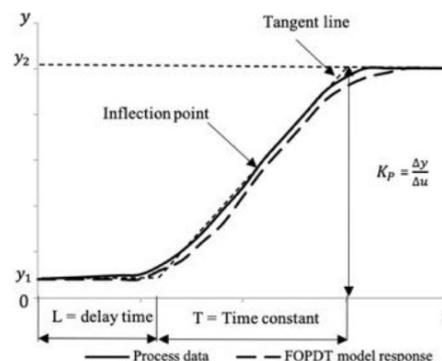


Figure 4. Determining PID Model FOPDT Parameters

Based on this figure, several response characteristics are obtained, including delay time (L), time constant (T), and process gain (Kp), as well as control parameters (Kc, Ti, Td). Through the PID control model, as in Figure 3 and the response in Figure 4, the process transfer function Gp(s) and control transfer function Gc(s) are obtained as follows:

$$G_p(s) = \frac{K_p}{1 + T_s} e^{-Ls} \tag{2}$$

$$G_c(s) = K_c \left( 1 + \frac{1}{T_i s} + T_d s \right) \tag{3}$$

$$G_c(s) = K_c + \frac{K_i}{s} + K_d s \tag{4}$$

From this equation,  $K_i = K_c/T_i$ , where  $T_i$  is the integral of constant time.  $K_d = K_c \times T_d$ , where  $T_d$  is the derivative of constant time. Meanwhile, to obtain the  $K_c$ ,  $T_i$ , and  $T_d$  values, a tuning method is needed. The equation below is a C-C PID tuning method that can be used for the FOPDT model [24].

$$\text{Proportional Gain (Kc)} = \frac{T}{K_p L} \left[ \frac{4}{3} + \frac{L}{4T} \right] \tag{5}$$

$$\text{Integral Time (Ti)} = \frac{L \left[ 32 + \frac{6L}{T} \right]}{13 + \frac{8L}{T}} \tag{6}$$

$$\text{Derivative Time (Td)} = \frac{4L}{11 + \frac{2L}{T}} \tag{7}$$

**Cohen-Coon Tuning Method for Incubator Controller**

By applying the theory, the input step results are obtained in the form of an S curve as in Figure 5. This curve is then plotted to obtain the parameters used to reach the set point temperature of 32 °C.

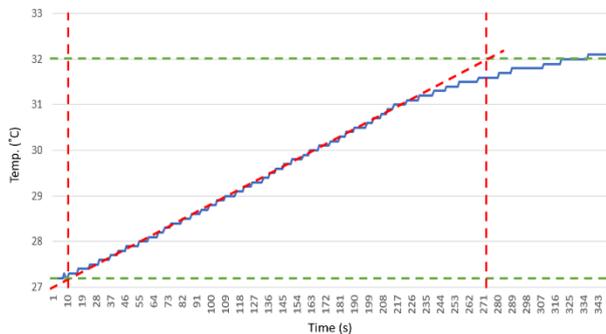


Figure 5. Response Results Determining Tuning Parameters

Based on the system response curve obtained, the values of T and L are determined as in the C-C PID tuning method of the FOPDT model, namely  $L = 10$  and  $T = 273$ . Furthermore, the T and L values in the system response graph can be used to find the ideal  $K_p$ ,  $K_i$ , and  $K_d$  parameters for the designed control system (tuning process). Below are the results of the C-C PID tuning calculation for the FOPDT model of the system:

**Calculation of the Kp Parameter**

$$K_p = \frac{273}{1.10} \left[ \frac{4}{3} + \frac{10}{4.273} \right] \tag{8}$$

$$K_p = 36,51 \tag{9}$$

**Calculation of the Ki Parameter**

$$T_i = \frac{10 \left( 32 + \frac{6 \cdot 10}{273} \right)}{13 + \frac{8 \cdot 10}{273}} \tag{10}$$

$$T_i = 24,24 \tag{11}$$

$$K_i = \frac{36,51}{24,24} = 1,51 \tag{12}$$

**Calculation of the Kd Parameter**

$$T_d = \frac{4 \cdot 10}{11 + \frac{2 \cdot 10}{273}} \tag{13}$$

$$T_d = 3,61 \tag{14}$$

$$K_d = 36,51 \times 3,61 \tag{15}$$

$$K_d = 131,80 \tag{16}$$

Using the Cohen Coon method with the FOPDT model, PID parameter values were obtained with  $K_p = 36.51$ ,  $K_i = 1.51$ , and  $K_d = 131.80$ , which were then entered into the Arduino program, and the results of the system response characteristics were observed after being given the PID values.

**Control Diagram and Flowchart**

The control diagram employs a closed-loop model, as shown in Figure 6(a). Based on this diagram, C-C PID only focuses on controlling the heating lamp. The system input is derived from the temperature inside the incubator, as detected by the DHT22 sensor. Then, the temperature will be processed using the C-C PID control with parameters  $K_p$ ,  $K_i$ , and  $K_d$ , based on the previous tuning results. The control system that is built is used to dynamically adjust the light intensity of the heating lamp according to the input temperature. The result is a stable incubator temperature of 32 °C, according to the setpoint. The sensor used also supports the incubator to have a closed-loop system.

Meanwhile, the DC fan operates outside PID control, receiving commands to regulate the incubator’s humidity, as shown in Figure 6(b). Similar to the temperature control system, humidity control also receives system input from the DHT22 sensor's detection results. The difference is that humidity control does not use PID control. The L298N driver controls the fan's condition, allowing it to turn on or off at a specific humidity level. Humidity control also has a closed-loop system.

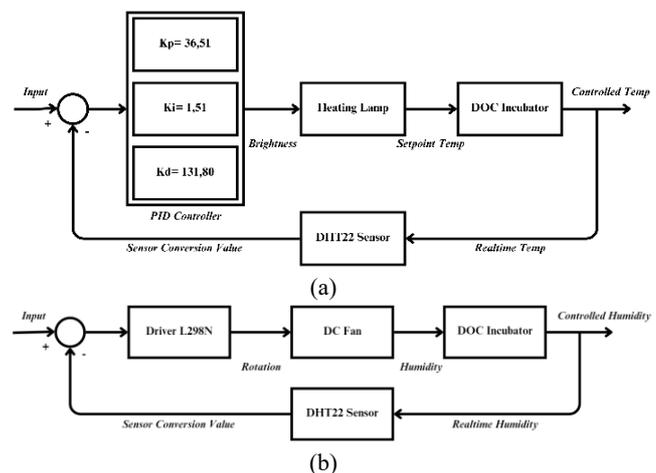


Figure 6. (a) and (b) DOC Incubator Control System Diagram

The flowchart in Figure 7 shows that the PID control system used has a set point value of 32 °C. Meanwhile, to achieve this temperature, the C-C PID is used. When the measured temperature is greater than the set point (error > 0), the PID will try to reduce the heating lamp voltage. This has an impact on reducing the incubator temperature, allowing it to approach the set point temperature. If the measured temperature is below the setpoint, then the opposite will happen.

To regulate the humidity of the incubator, DC fan control is used, which is separate from the C-C PID control system. In the flowchart, it appears that humidity control occurs after the temperature control process is completed. The measured humidity will be identified by the system. If the humidity is above 50%, the DC fan will be turned on until the humidity falls below it again.

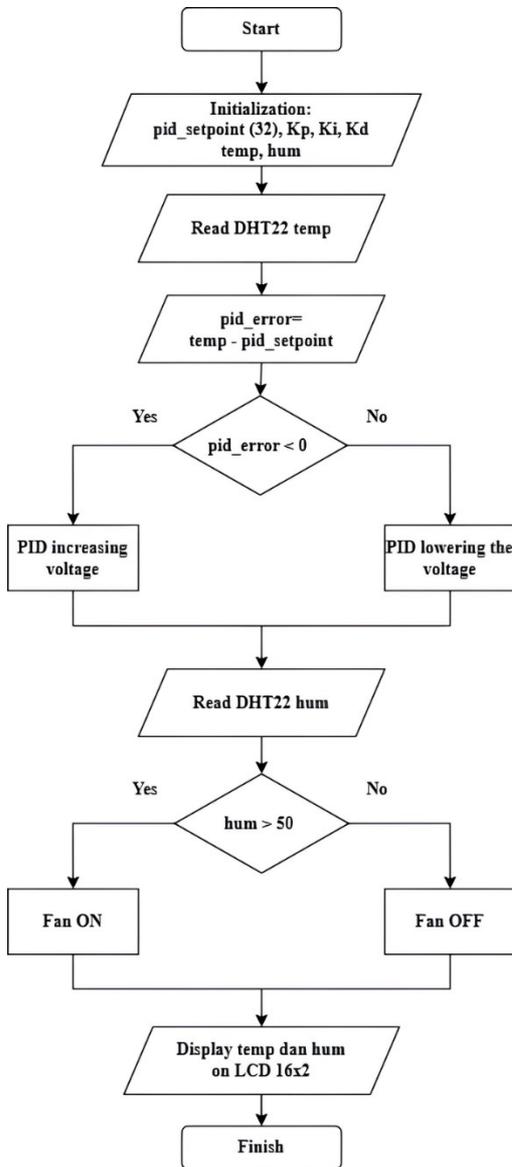


Figure 7. DOC Incubator Flowchart

## RESULTS AND DISCUSSION

### DHT22 Sensor Reliability

After calibration or adjustment between a DHT22 sensor and a thermometer, the measurements obtained with the DHT22 sensor showed a slight difference compared to those made using a thermometer. Based on the comparison graph in Figure 8, the average error in the incubator humidity measurement system using the DHT22 sensor is only 0.59%. The biggest error occurred in the 5th measurement, with an error of 1.1%. The temperature reading from the DHT22 sensor was approximately 28.7 °C, and the thermometer read 28.4 °C. The smallest error occurred in the 7th measurement at 29,1 °C and the 11th

measurement at 30,5 °C, with an error of 0% or precision according to the thermometer.

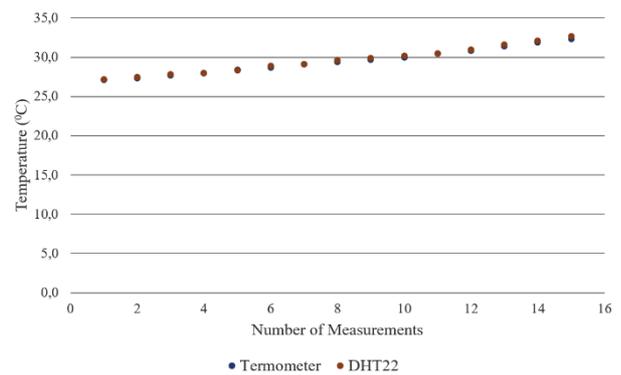


Figure 8. Temperature Measurement Graph After Calibration

Furthermore, based on the comparison graph in Figure 9, the average error in the incubator humidity measurement system using the DHT22 sensor is 5.02% (slightly larger than the error in temperature measurements). The biggest error occurred in the 2nd measurement, with an error of 11.1%. It was approximately 63.3% on the DHT22 sensor and 57% on the hygrometer. The smallest error occurred in the 8th measurement, at 60.6% on the DHT22 sensor and 61% on the hygrometer, with an error of 0.7%.

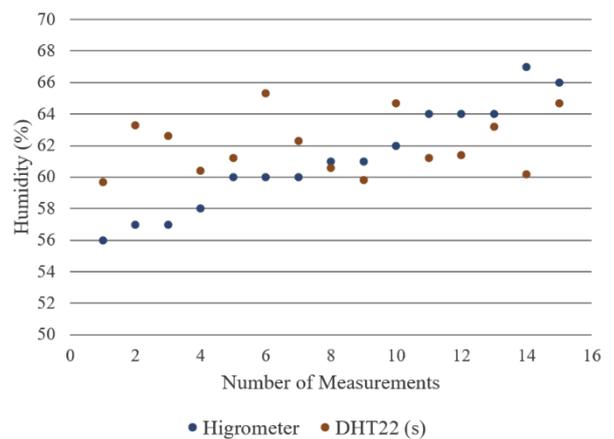


Figure 9. Humidity Measurement Graph After Calibration

### Tuning Results from C-C PID

Based on the tuning results obtained, the response of the C-C PID control is tested using the parameters  $K_p = 36.51$ ,  $K_i = 1.51$ , and  $K_d = 131.80$ . The response results from the C-C PID control with the FOPDT model are shown in Figure 10. Based on this image, the observed response characteristics are obtained from the moment the input temperature changes until the response enters a steady state. The response graphic results obtained are considered stable and suitable for application in Joper DOC incubators.

Based on the graph obtained, several indicators can be determined to determine the success of the system, such as rise time ( $T_r$ ), overshoot ( $M\%$ ), settling time ( $T_s$ ), and steady-state error conditions ( $E_{ss}$ ). Generally, the rise time value can be measured based on the time it takes for the temperature to reach 10% to 90% of the set point. It can be seen that the temperature increases from 27.86 °C (10%) to 31.54 °C (90%) and requires a rise time of

±225 seconds. The overshoot value can be calculated using the following equation:

$$M\% = ((\text{peak temperature} - \text{set point}) \div \text{setpoint}) \times 100\% \quad (15)$$

$$M\% = ((32,5 \text{ }^\circ\text{C} - 32 \text{ }^\circ\text{C}) \div 32 \text{ }^\circ\text{C}) \times 100\% \quad (16)$$

$$M\% = 1,56\% \quad (17)$$

For settling time, or the time required for the system to reach ±2% of the set point, it can be seen that the system requires approximately 510 seconds. The steady-state error for the system is almost zero because the final measured temperature is very close to the set point temperature. Based on the indicators obtained from the PID response graph in Figure 10, the system successfully reaches and maintains a temperature around the set point, with a small overshoot and a reasonable settling time. This indicates that C-C PID tuning has achieved optimal results.

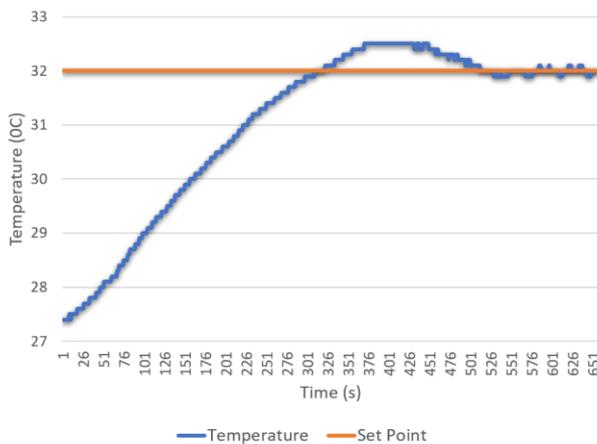


Figure 10. System Response C-C PID After Tuning

**Incubator Success Rate**

During overall system testing, the entire device is tested, as shown in Table 1. The system appears to be working very well. The temperature can reach the setpoint stably. Additionally, the system can maintain humidity by adjusting the fan's on/off conditions.

Table 1. Overall Testing of the DOC Incubator

Time	Temperature (°C)	Setpoint (°C)	Error (%)	Humidity (%)	DC Fan Condition
19.06	27,7	32,0	13,44	56,3	ON
19.10	31,6	32,0	1,25	47,7	OFF
19.15	32,0	32,0	0,00	48,6	OFF
19.20	31,9	32,0	0,31	49,1	OFF
19.25	31,9	32,0	0,00	49,8	OFF
19.30	32,0	32,0	0,00	48,8	OFF
19.35	32,0	32,0	0,00	48,8	OFF

The results of testing the incubator for 30 minutes indicated that the tool functioned as specified. As shown in Figure 11, the lowest temperature in the incubator was 27.7 °C, which was maintained from the start of the test and stabilized at the set point by the 10th minute of the incubator measurement. During the testing process, the temperature slightly decreased at the 19th minute. The hypothesis that can be drawn from this condition is that, within the same minute, there is an increase in humidity of up to 50% or more, which causes the fan to turn on and results in a slight decrease in temperature to 31.8 °C. However, the temperature managed to reach the set point value of 32 °C again.

This study also performs statistical validation by calculating the confidence interval for measurement errors. Based on the temperature data analysis, the 95% confidence interval for measurement errors in the incubator system is (-0.742, 0.042). This indicates that the system maintains a high level of accuracy in regulating the temperature close to the 32°C setpoint, with a slight tendency toward negative errors.

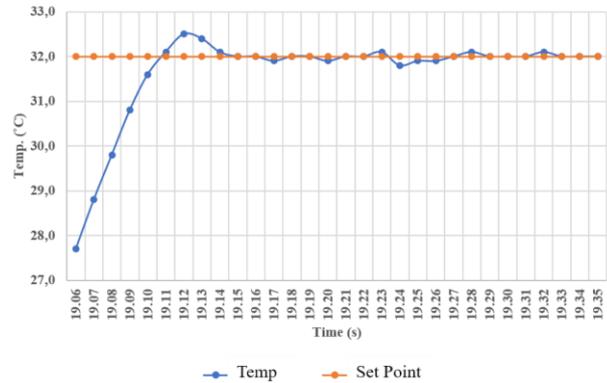


Figure 11. DOC Measured Temperature Graph on Incubator

The next test was conducted to assess the incubator's ability to reduce the mortality rate of Joper DOC. This test was conducted on a 3-day-old Joper DOC, which was hatched, for 7 days after it was first placed in the incubator. Monitoring is carried out every day and then recorded and documented as material for analyzing the results of the incubator's work. The number of Joper DOC used in the test was 16 birds, and after 7 days of monitoring, no chickens died. This shows that the incubator can reduce the mortality rate to 0% in Joper DOC chickens. The test results are presented in Table 2.

**Operational Limitations and Advantages Offered**

This study has several operational limitations that allow it to focus on the desired scope of discussion. Here are some of the operational limitations: 1. This study only focuses on the incubation object in the form of DOC joper chickens aged 1-7 days; 2. This study only uses the Cohen Coon PID tuning method as a temperature control algorithm with a set point of 32 °C 3. The Cohen Coon PID tuning control system focuses on temperature control using a special incubator heating lamp with a power of 25 watts. Humidity control using a fan and L298N driver without involving PID control; 5. The voltage source used is supplied by PLN in uninterrupted or blackout conditions.

The advantage of this incubator lies in its stability and good temperature distribution. This is influenced by the use of four DHT22 sensors placed on each side of the incubator, ensuring more even temperature detection and avoiding concentration in a single location. Additionally, the use of PID control enhances temperature control stability. PID control ensures the heating lamp remains on, while the lighting intensity is constantly adjusted to match the real-time temperature. Equipped with excellent temperature control, this incubator can reduce mortality rates to 0%. This incubator is able to answer the challenges of previous research which resulted in a 20% mortality rate and 75% in temperature stability [25].

Table 2. DOC Incubator Effectiveness Test

Day	Alive DOC	Mortality (%)	Documentary
1	16	0,00	
2	16	0,00	
3	16	0,00	
4	16	0,00	
5	16	0,00	
6	16	0,00	
7	16	0,00	

## CONCLUSIONS

Several main conclusions can be drawn, including accuracy level testing, which show that the DHT22 sensor can measure temperature and humidity well. After calibration, the temperature measurement error is 0.59% and the humidity is 5.02%. C-C PID control has also been proven to be successful, proven by several indicators such as short rise time values ( $\pm 225$  seconds), achieving settling time within a reasonable time range ( $\pm 510$  seconds), low overshoot ( $\pm 1.56\%$ ), and steady-state error is close to 0%. Based on the temperature data analysis, the 95% confidence interval for measurement errors in the incubator system is (-0.742, 0.042). Overall, the system can be considered successful in regulating temperature and humidity automatically. In 30 minutes of testing, the incubator can maintain stable temperature conditions at a set point temperature of 32 °C and humidity below 50% automatically. The designed incubator has also been proven effective in reducing the DOC mortality rate of Joper chickens to 0%, resulting in no deaths at all.

## REFERENCES

- [1] C. Diwangkara and R. Handarini, "Persentase Daging Nirtulang Ayam Kampung Jawa Super Yang Diberi Tepung Serai Wangi (*Cymbopogon Nardus*) dalam Ransum Percentage of Boneless Meat of Jawa Super Native Chicken were Given Citronella Meal (*Cymbopogon nardus*) in The Ration," *Jurnal Peternakan Nusantara*, vol. 10, no. 1, pp. 37–46, 2024, <https://doi.org/10.30997/jpn.v10i1.12990>.
- [2] D. . Afiyah, Supriyoni, R. . Sarbini, and I. N. . Rosikhulhaj, "Pengaruh Substitusi Tepung Jerami Bawang Merah terhadap Performa Produksi Ayam Joper," *SENACENTER*, no. 38, pp. 61–65, 2022, <https://doi.org/10.32503/senacenter.v1i1.12>.
- [3] N. Kaleka, "Beternak Ayam Kampung Super dan Jawa Super Tanpa Bau," *Yogyakarta Arcitra*, 1st ed., pp. 1-192, ISBN: 978-602-784-941-9, 2015, <https://balaiyanpus.jogjaprovo.go.id/opac/detail-opac?id=318931>.
- [4] M. N. Wahid, L. A. Lukito Afandy, P. Slamet, and N. A. Basyarach, "Pengendali Suhu Ruang Inkubator Doc Berbasis Plc," *El Sains J. Elektro*, vol. 1, no. 2, pp. 1–5, 2020, <https://doi.org/10.30996/elsains.v1i2.3192>.
- [5] F. H. Mustianto, Asni Tafrikhatin, and Ajeng Tiara Wulandari, "Rancang Bangun Pengatur Suhu Kandang Ayam Otomatis Menggunakan Sensor DHT22 Berbasis Wemos D1 R32 Dengan Keluaran Berupa LCD dan Notifikasi Telegram," *JASATEC J. Students Automotive, Electron. Comput.*, vol. 2, no. 1, pp. 9–19, 2023, <https://doi.org/10.37339/jasatec.v2i1.1237>.
- [6] N. Haidar Hari and I. Darmawan, "Sistem Pengontrol Suhu Pada Kandang Brooding Dengan Logika Fuzzy Menggunakan Arduino Uno Berbasis Mobile," *J. Responsif Ris. Sains dan Inform.*, vol. 5, no. 1, pp. 43–51, 2023, <https://doi.org/10.51977/jti.v5i1.1049>.
- [7] Suliono, Sunariyo, And F. Wadjdi, "Pengaruh Suhu Brooder Terhadap Suhu Tubuh, Bobot Badan dan Pertumbuhan Bulu Sayap Primer Ayam Parentstock Strain Cobb Umur Satu Minggu," *J. Din. Rekasatwa*, vol. 5, no. 3, pp. 255–258, 2022, <https://jim.unisma.ac.id/index.php/fapet/article/view/18232>.

- [8] T. Hadyanto and M. F. Amrullah, "Sistem Monitoring Suhu dan Kelembaban pada Kandang Anak Ayam Broiler Berbasis Internet Of Things." *J. Teknologi dan Sistem Tertanam*, vol. 03, no. 02, pp. 9-22, 2022, <https://ejurnal.teknokrat.ac.id/index.php/jtst/article/view/2179>.
- [9] R. Y. Parapat, E. Sandjaya, S. A. Nurfadhilah, M. M. Fetok, N. Hikmah, and Salaffudin, "Kesejahteraan Ayam Broiler Pada Sistem Kandang Free-Range dan Kandang Tertutup (Closed-House)", *Scientica: J. Ilmiah Sains dan Teknologi* vol. 3, no. 2, pp. 657-664, 2024, <https://jurnal.kolibi.org/index.php/scientica/article/view/4547>.
- [10] Zulfachmi and A. Nong, "Kajian Performa Ayam Broiler Berdasarkan Iklim Mikro pada Kandang Closed House Evaporated Cooling Pad System," *SNISTEK*, vol. 4, pp. 1-7, 2022, <https://ejournal.upbatam.ac.id/index.php/prosiding/article/view/5195>.
- [11] M. I. Maulana, D. Garnida, I. Setiawan, and Y. Yudiantara, "Kajian Performa Ayam Broiler Berdasarkan Iklim Mikro pada Kandang Closed House Evaporated Cooling Pad System," *J. Anim. Husb. Sci.*, vol. 8, no. 2, pp. 74-86, 2024, <https://doi.org/10.52434/janhus.v8i2.3495>.
- [12] A. Febriawan and W. S. Aji, "Rotating Control on Robots Indonesian Abu Robot Contest with PID and IMUBNO055 Controls," *Bul. Ilm. Sarj. Tek. Elektro*, vol. 2, no. 1, p. 14, 2020, <https://doi.org/10.12928/biste.v1i3.987>.
- [13] H. Supriyono, F. F. Alanro, and A. Supardi, "Development of DC Motor Speed Control Using PID Based on Arduino and Matlab For Laboratory Trainer," *J. Nas. Tek. Elektro*, vol. 1, pp. 36-41, 2024, <https://doi.org/10.25077/jnte.v13n1.1155>.
- [14] C. T. Chao, N. Sutarna, J. S. Chiou, and C. J. Wang, "An optimal fuzzy PID controller design based on conventional PID control and nonlinear factors," *Appl. Sci.*, vol. 9, no. 6, 2019, <https://doi.org/10.3390/app9061224>.
- [15] A. Ma'arif, R. Istiarno, and S. Sunardi, "Kontrol Proporsional Integral Derivatif (PID) pada Kecepatan Sudut Motor DC dengan Pemodelan Identifikasi Sistem dan Tuning," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, vol. 9, no. 2, p. 374, 2021, <https://doi.org/10.26760/elkomika.v9i2.374>.
- [16] A. Ma, R. Dwi Puriyanto, N. Maharani Raharja, and S. Nurindra Rahmadhia, "Arduino Embedded Control System of DC Motor Using Proportional Integral Derivative," *SERSC Int. J. Control Autom.*, vol. 13, no. 4, pp. 658-667, 2020, <http://sersc.org/journals/index.php/IJCA/article/view/18854>.
- [17] A. Latif, K. Shankar, and P. T. Nguyen, "Legged Fire Fighter Robot Movement Using PID," *Journal of Robotics and Control (JRC)*, vol. 1, no. 1, pp. 15-18, 2020, <https://doi.org/10.18196/jrc.1104>.
- [18] J. de Souza Granja Barros, L. A. Rossi, and Z. Menezes de Souza, "PID temperature controller in pig nursery: spatial characterization of thermal environment," *Int. J. Biometeorol.*, vol. 62, no. 5, pp. 773-781, 2018, <https://doi.org/10.1007/s00484-017-1479-x>.
- [19] M. I. Rusydi, "Optimasi Pengendali PID pada Pesawat Autopilot Berbasis Algoritma Genetika," *J. Nas. Tek. Elektro*, vol. 5, no. 2, p. 217, 2016, <https://doi.org/10.25077/jnte.v5n2.267.2016>.
- [20] M. R. Djalal, H. Nurohmah, A. Imran, and M. Y. Yunus, "Aplikasi Metode Cerdas untuk Optimasi Controller PID Motor DC Berbasis Firefly Algorithm," *J. Nas. Tek. Elektro*, vol. 6, no. 2, p. 76, 2017, <https://doi.org/10.25077/jnte.v6n2.393.2017>.
- [21] L. S. Mezher, "Position control for dynamic DC MOTOR with robust PID controller using MATLAB," *Int. J. Adv. Trends Comput. Sci. Eng.*, vol. 8, no. 3, pp. 936-942, 2019, <https://doi.org/10.30534/ijatcse/2019/92832019>.
- [22] R. Bitriá and J. Palacín, "Optimal PID Control of a Brushed DC Motor with an Embedded Low-Cost Magnetic Quadrature Encoder for Improved Step Overshoot and Undershoot Responses in a Mobile Robot Application," *Sensors*, vol. 22, no. 20, 2022, <https://doi.org/10.3390/s22207817>.
- [23] T. Alamirew, V. Balaji, and N. Gabbeye, "Design of model predictive controller for pasteurization process," *Indones. J. Electr. Eng. Informatics*, vol. 5, no. 2, pp. 137-144, 2017, <https://doi.org/10.11591/ijeeci.v5i2.279>.
- [24] T. Suksawat, and P. Kaewpradit, "Comparison of Ziegler-Nichols and Cohen-Coon Tuning Methods: Implementation to Water Level Control Based MATLAB and Arduino," *Eng. J. CMU*, vol. 28, no. 1, pp. 153-168, 2021, <https://ph01.tci-thaijo.org/index.php/EngJCMU/article/view/243443>.
- [25] M. Supriyanto and D. Rahmawati, "Rancang Bangun Inkubator Anak Ayam Doc (Day Old Chick) Otomatis Berbasis Mikrokontroler," *JE-Unisla*, vol. 5, no. 1, pp. 315-320, 2020, <https://doi.org/10.30736/je.v5i1.419>.

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