Signal and Image Processing Letters
Vol. 7., No. 1, 2025, pp. 63-71
ISSN 2714-6677
https://simple.ascee.org/

Optimization Day Old Chick Incubator Design to Reduce Mortality Rate Using Fuzzy Logic

Adi Kurniawan Saputro [a,1,*], Muhammad Fajar Ramadhan [a,2], Achmad Fiqhi Ibaidilah [a,3], Haryanto [a,4], Hanifudin Sukri [a,5], Muttaqin Hardiwansyah [a,6]

[a] Faculty of Engineering, Departement Of Electrical Engineering, Universitas Trunojoyo Madura, Indonesia
[1] adi.kurniawan@trunojoyo.ac.id; [2] fajaramadhan991@gmail.com; [3] fiqhi.ibadila@trunojoyo.ac.id; [4] haryanto@trunojoyo.ac.id;
[5] hanifudinsukri@trunojoyo.ac.id; [6] muttaqin.hardiwansyah@trunojoyo.ac.id
* corresponding author

ARTICLE INFO

Keywords
Day-Old Chick (DOC)
ESP 32
MQ-135
DHT22
Internet of Things (IoT) Technology

ABSTRACT

In poultry farming, particularly for Day-Old Chicks (DOC), maintaining an ideal environmental condition is a significant challenge due to the limited ability of mother hens to provide adequate warmth and care. This often leads to a high mortality rate among DOC, especially in broiler chickens. The research contribution is the development of an intelligent incubator system based on fuzzy logic to automate environmental control and reduce DOC mortality rates. The system employs a DHT22 sensor to measure temperature and humidity, and an MQ-135 sensor to detect ammonia levels. An ESP32 microcontroller is used for data processing, chosen for its built-in Wi-Fi capability and high processing power. The DHT22 sensor controls a fan and UVA+UVB lamp via an AC dimmer, while the MQ-135 sensor controls a DC motor through the L298N driver. The fuzzy logic method is applied to make more accurate control decisions, and the entire system is connected to an IoT-based monitoring platform that provides a real-time dashboard for farmers. Preliminary results show that the system successfully maintains temperature within the optimal range (30–34°C) and humidity (40–70%), and responds efficiently to changes in ammonia concentration. Compared to conventional systems, this intelligent incubator offers better automation, lower energy consumption, and cost efficiency. In conclusion, the proposed system provides a scalable and efficient solution for DOC management. Future work includes AI-based prediction integration, mobile application development, and historical data analysis for smarter poultry farm management.

1. Introduction

Indonesia has a strategic geographical location with a majority of its population working in the agricultural sector, including livestock farming. Animal husbandry plays a crucial role in supporting national food security by providing essential animal-based protein sources such as meat, eggs, and milk. These products are vital for meeting the nutritional needs of the population. Therefore, the development of the livestock sector is a national priority, aiming to ensure the availability of food that is safe, healthy, whole, and halal (ASUH), while promoting rural economic growth [1]. Among the livestock commonly raised in rural areas, free-range chickens are valued for their dual purpose—egg and meat production—as well as a form of economic savings. In addition, livestock such as chickens, goats, and cattle are essential for cultural and religious events like Eid al-Fitr, Eid al-Adha, and aqiqah. Chicken meat and eggs, in particular, are affordable and accessible sources of animal protein [2].

Despite its potential, poultry farming—especially for Day-Old Chicks (DOC)—faces serious challenges. One key issue is the high mortality rate among DOCs caused by improper environmental conditions, particularly temperature fluctuations [3]. Studies show that the optimal temperature for DOCs ranges from 30°C to 34°C [4][5]. Temperatures outside this range can be fatal to the chicks. Given the increasing demand for poultry products, improving DOC survival rates is critical.

Incubators are widely used in poultry farms to replace the role of the mother hen, enabling large-scale chick rearing. However, many conventional incubators lack automation and require constant manual supervision. This limitation increases labor costs and the risk of human error [6]. To address this issue, recent developments have focused on integrating Internet of Things (IoT) technologies into incubator systems. IoT-based incubators offer several advantages, such as real-time monitoring and control of environmental conditions like temperature, humidity, and ammonia levels [7][8]. These systems enable farmers to remotely access data and make timely decisions, thereby improving operational efficiency and reducing DOC mortality. Moreover, IoT systems support data logging and analysis, allowing for smarter and more informed farm management [9].

Despite the benefits of IoT, an effective control system is also essential for maintaining optimal conditions. Fuzzy logic is chosen in this research due to its robustness in handling imprecise and nonlinear data, making it more adaptable than traditional methods like PID controllers in real-world farming scenarios. This research proposes the development of an intelligent incubator system that integrates fuzzy logic with IoT technology to automatically control environmental conditions for DOCs. The system utilizes a DHT22 sensor for temperature and humidity monitoring, and an MQ-135 sensor for ammonia detection, with data processed by an ESP32 microcontroller. Compared to existing incubators, this system offers improved automation, scalability, and cost-efficiency. In addition to technical innovation, the system is designed with small-scale farmers in mind—providing an affordable and sustainable solution that boosts productivity and reduces labor dependency. Ultimately, this research contributes to improving food security and advancing sustainable poultry farming in Indonesia.

2. Methods

This study employs an experimental approach through the stages of designing and implementing a temperature, humidity, and ammonia gas control system based on Mamdani fuzzy logic. The system is integrated with an IoT platform using the ESP32 microcontroller. The research procedure consists of system design, hardware assembly, software development, and system testing and performance analysis. The hardware components include sensors for temperature and humidity (DHT22) and ammonia gas (MQ-135), interfaced with the ESP32 microcontroller. The software implements fuzzy Mamdani logic to process sensor inputs and control outputs to maintain environmental conditions suitable for broiler chicken rearing. Testing was conducted continuously over a 14-day period in a controlled environment simulating broiler housing conditions. Data collected during testing include temperature, humidity, ammonia levels, and system responses such as fan speed, lamp intensity, and motor operation. Performance analysis was carried out by comparing the system's automated control outputs against predefined environmental standards for broiler maintenance. The effectiveness of the fuzzy logic control system in maintaining optimal conditions was evaluated based on stability, responsiveness, and accuracy of the controlled environment variables.

2.1. Fuzzy

Fuzzy logic differs from conventional binary logic (crisp logic), which only has strictly true or false values. In fuzzy logic, membership values can range between 0 and 1, allowing fuzzy control systems to operate like the human nervous system, responding more flexibly to environmental conditions—something conventional control systems lack [10]. This study uses the Mamdani fuzzy method with three inputs: temperature, humidity, and ammonia levels, and three outputs: UVA + UVB lights, DC fan, and DC motor. An example of input-output mapping for the temperature range of 25°C to 35°C is as follows: temperatures below 27°C trigger the UVA + UVB lights to turn on for heating, temperatures between 27°C and 31°C activate the DC fan at medium speed to maintain coolness, and temperatures above 31°C increase the speed of the fan and DC motor for maximum cooling. The Mamdani method was chosen due to its ability to model rule-based control systems that are easy to understand and implement, with outputs in the form of fuzzy functions that are intuitive and easy to interpret directly. Unlike the Sugeno method, which is more suitable for mathematical optimization and systems with linear output functions, Mamdani is more appropriate for control applications based on human experience or rules, such as environmental regulation in broiler chicken coops.

2.2. Internet Of Things

The Internet of Things (IoT) refers to objects that can transfer data over a network without requiring direct human interaction. In this system, the ESP32 microcontroller enables seamless IoT connectivity by supporting Wi-Fi communication, allowing real-time data transmission and remote monitoring of environmental conditions. The ESP32 can use protocols such as MQTT and HTTP to efficiently send sensor data (temperature, humidity, ammonia) to cloud platforms or user interfaces, enabling automated control and data analysis. Thus, IoT integrates smart devices to recognize and communicate with each other, creating an interconnected environment for optimized broiler chicken coop management [11]–[13].

2.3. Broiler Chicken

Broiler chickens (meat chickens) are categorized as chickens with the advantage of being able to convert the feed they consume into meat efficiently. Due to this advantage, broiler chickens are generally ready for harvest at around 28 to 45 days of age, with an average body weight ranging from 1.2 to 2 kg per bird. These chickens are widely consumed by the public as a daily food source. The ideal brooding temperature for broiler chicks during the brooder phase ranges between 30-32°C[14].

2.4. ESP 32

The ESP32 is a microcontroller developed by Espressif Systems and serves as the successor to the ESP8266 microcontroller. It features a dual-core processor, built-in Wi-Fi and Bluetooth connectivity, and low power consumption, making it ideal for IoT-based control systems that require wireless communication and efficient multitasking. All GPIO pins are labeled on the top of the board, making them easy to identify and connect to various sensors and actuators. Programming is simplified through the USB to UART interface, which is compatible with development platforms such as the Arduino IDE. Power can be supplied via a micro USB connector [15]. In this system, the ESP32 was selected due to its high performance, integrated wireless features, and affordability compared to other microcontrollers. The GPIO pins used include GPIO4 for the DHT22 sensor (temperature and humidity), GPIO34 for the MQ-135 gas sensor (ammonia), GPIO18 for controlling a DC fan, ,GPIO19 for the DC motor, and GPIO23 for the UVA+UVB lamp dimmer.

2.5. DHT 22

The DHT22 is a digital temperature and humidity sensor that provides accurate and stable measurements, making it suitable for environmental monitoring applications. It operates within a wide temperature range of -40°C to 80°C with an accuracy of ±0.5°C, and can measure humidity from 0% to 100% with an accuracy of ±2–5%. Compared to similar sensors like the DHT11, the DHT22 offers better precision, a broader range, and greater long-term stability. Its digital output simplifies data acquisition using microcontrollers, as it requires only one GPIO pin for communication, reducing wiring complexity and improving system integration efficiency

2.6. MQ-135

The MQ-135 gas sensor is chosen for its ability to detect harmful gases such as ammonia (NH_3), carbon dioxide (CO_2), and volatile organic compounds (VOCs), making it suitable for monitoring air quality in broiler chicken farms. It offers high sensitivity, long-term stability, and easy integration with microcontrollers like the ESP32 for real-time IoT-based monitoring [16]-[20]. To ensure accurate readings, the sensor must be calibrated by determining its baseline resistance (R_o) in clean air, measuring the resistance (R_s) when exposed to target gases, calculating the R_s/R_o ratio, and converting it to gas concentration using a calibration curve or mathematical model.

3. Results and Discussion

3.1. Flowchart System

In Fig 1, the flowchart begins with selecting the mode type that has been provided. Then, the DHT22 sensor will read the temperature in the incubator according to the selected mode. If the temperature in the incubator is normal, the UVA + UVB lamp will light dimly and the DC fan will turn on. However, if the DHT22 sensor reads a temperature above the predetermined limit, the UVA

+ UVB lamp will turn off and the DC fan will remain on. If the temperature is read as cold by the DHT22 sensor, the UVA + UVB lamp will also be turned off. The temperature value read by the DHT22 sensor will be sent to the LCD, which can be viewed by the farmer. The MQ-135 sensor is a sensor that can detect odors from chicken waste. If the odor from the waste reaches the predetermined set point value, the DC motor will turn on according to the specified program. The MQ-135 sensor readings will also be sent to the LCD.

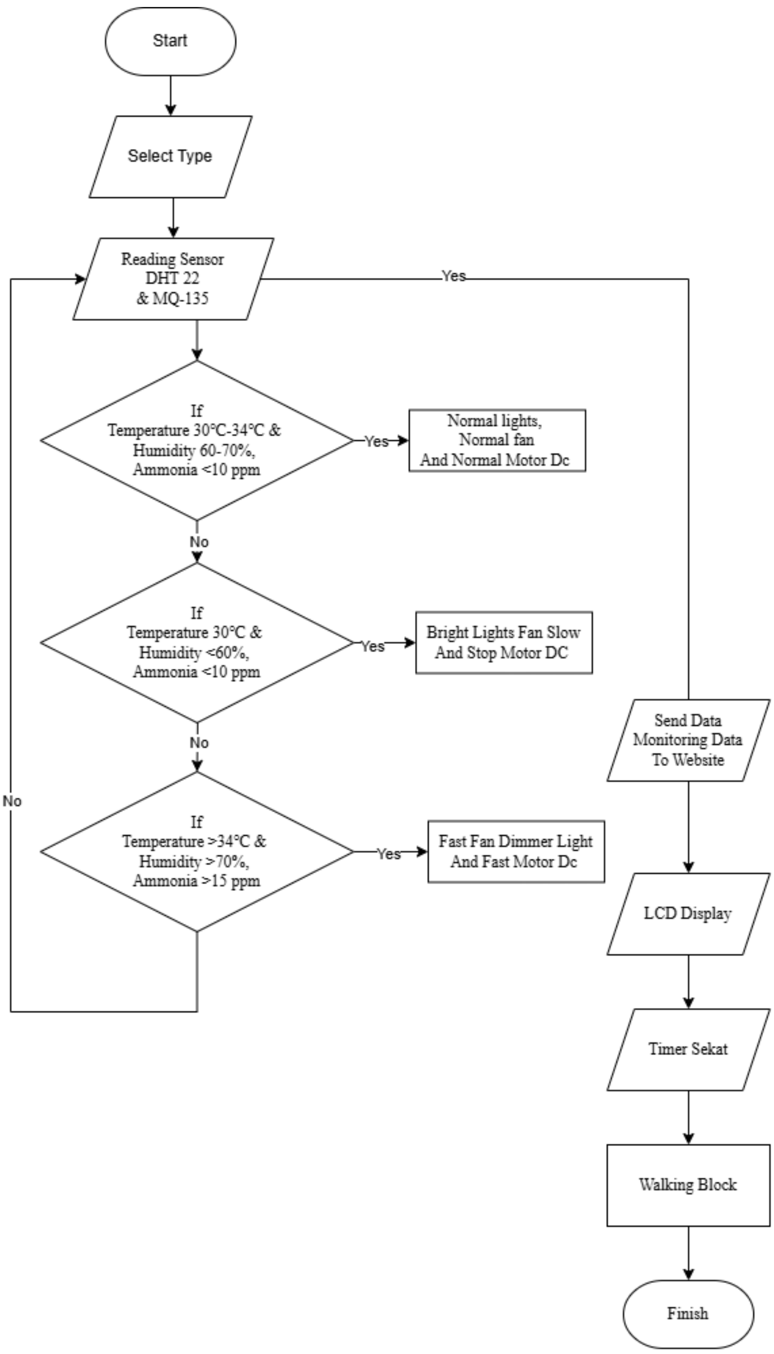

Fig. 1. Flowchart System

3.2. Wiring Diagram

In designing a fuzzy-based incubator system to reduce DOC (Day Old Chick) mortality, several electronic components are used to ensure proper function. Fig. 2 shows the wiring diagram with the input and output connections for the ESP32 microcontroller. The ESP32 acts as the main controller. Inputs include the DHT22 sensor for temperature and the MQ-135 sensor for ammonia gas. The DHT22 sends temperature data to the ESP32, which controls the UVA+UVB lamp and DC fan.

Outputs include a DC fan, UVA+UVB lamp, and DC motor. When temperature and humidity reach their set points, the fan and lamp will turn on. If ammonia levels exceed the limit, the DC motor activates. All sensor data is displayed on an LCD screen.

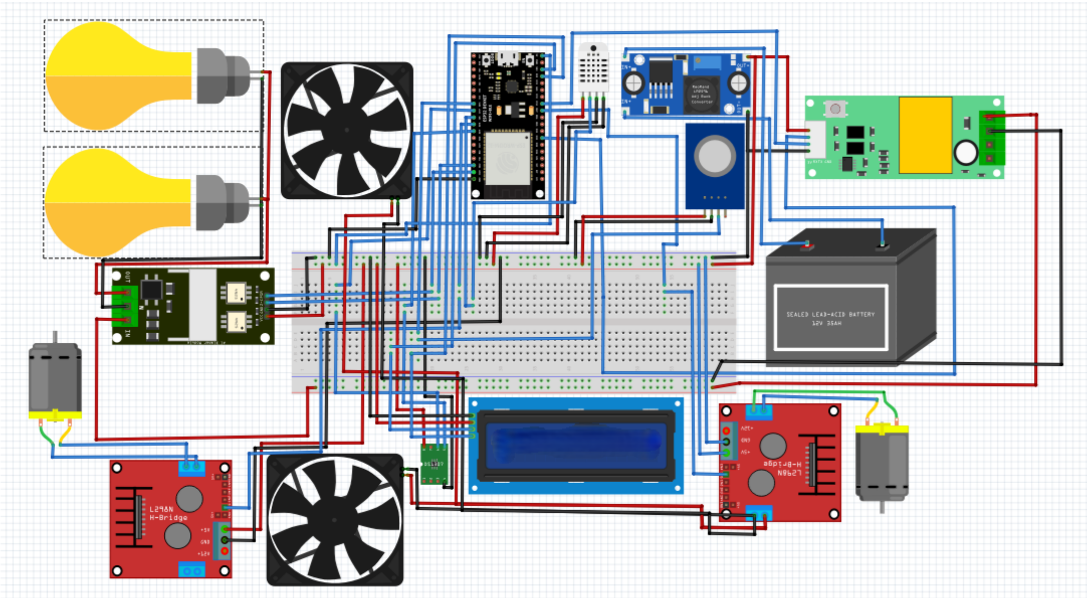

Fig. 2. Wiring Diagram

3.3. Prototype Design

The device has a wooden frame and several parts, each with its own function. A component box protects the electronics and keeps things tidy. The front is clear acrylic with a wooden frame, used as a door. The bottom has wire mesh so chicks don't touch the waste. The back and top are made of wood. Underneath, a conveyor helps remove waste easily. The design is made to work well and be practical to use. The incubator chamber measures 100 x 50 cm, providing sufficient space for the chicks during hatching can be seen in Fig. 3. Plywood (triplek) is selected as the main material for the frame due to its relatively low cost compared to solid wood, making it more economical. Additionally, plywood has favorable thermal properties, as it does not excessively retain heat generated by the incandescent lamp. This helps maintain a stable temperature inside the incubator while also supporting humidity regulation, making it suitable for controlled hatching environments can be seen in Fig 4.

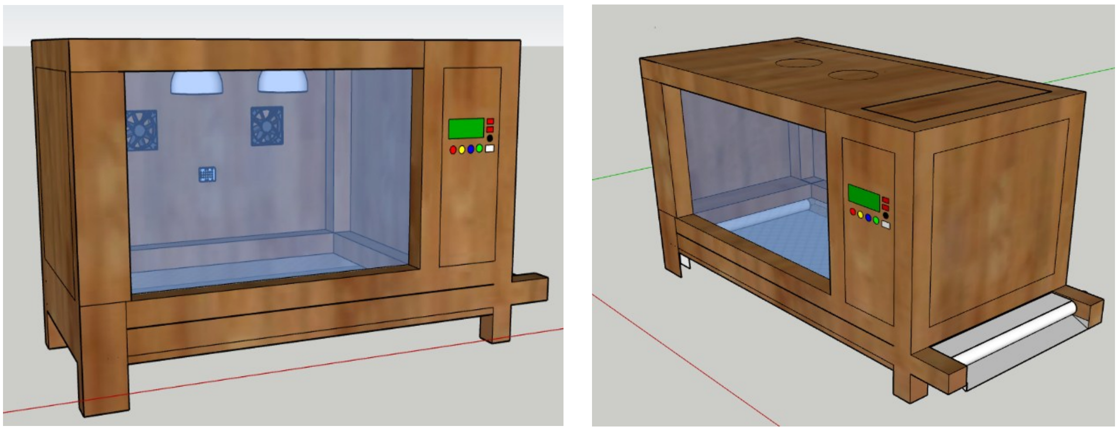

Fig. 3. 3D Design Optimization of DOC (Day Old Chick) Incubator Design to Reduce Mortality Rate Using Fuzzy Logic

Fig. 4. Prototype Optimization of DOC (Day Old Chick) Incubator Design to Reduce Mortality Rate Using Fuzzy Logic

3.4. Website Design for Optimizing the DOC (Day Old Chick) Incubator to Reduce Mortality Rate Using Fuzzy Logic

A website can be customized in layout, images, videos, and content. It is a common tool for sharing information and can also serve as a virtual communication platform [15]. A dynamic website has changing content, while a static website shows the same content without updates. In this study, the website is designed as a dynamic platform that retrieves data from the incubator every second. The data, which includes temperature, humidity, ammonia levels, and power consumption, is transmitted to a database in real time. This allows users to monitor and visualize the environmental conditions of the incubator directly through the website can be seen in Fig. 5.

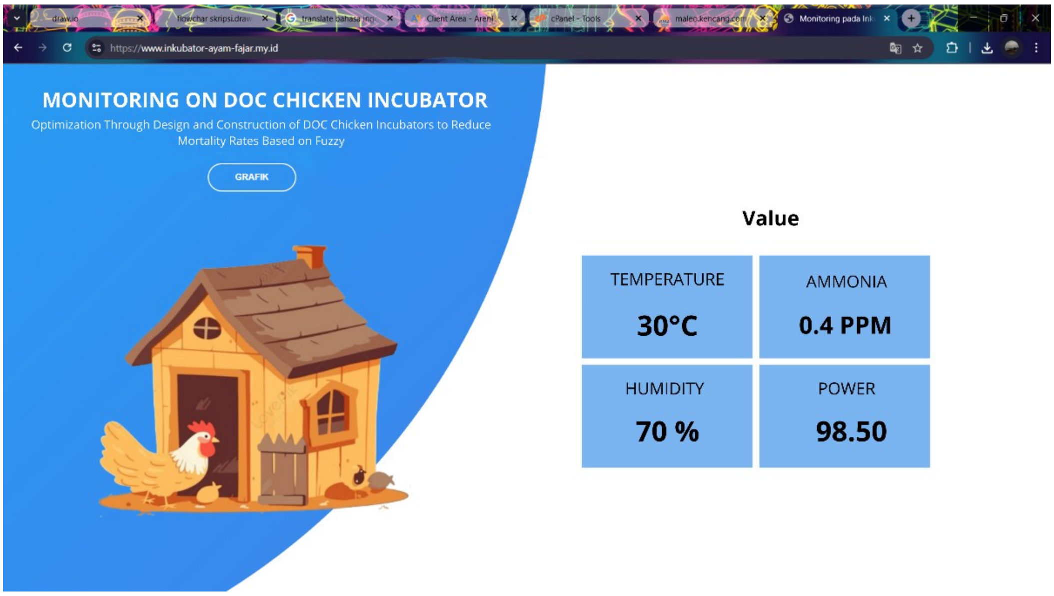

Fig. 5. Website Design for Optimizing the DOC (Day Old Chick) Incubator

3.5. Fuzzy Calculation

The Mamdani fuzzy calculation is carried out by converting crisp inputs into membership degrees using membership functions, then applying IF-THEN rules based on fuzzy logic, performing inference using MIN and MAX operators, and finally defuzzification—usually with the centroid method—to produce a crisp output as the final decision result can be seen in Fig. 6 and Fig. 7. Result can be seen in Table 1 and Table 2.

Fuzzification

$$\mu\,(x) = \begin{cases} \dfrac{(x-a)}{(b-a)}; & a \le x \le b \\ 0; & x \le c \end{cases}$$

Inference

$$\alpha - predicate = min\big(\mu\ \mathrm{a}\ (\mathrm{x}) \cap \mu\ \mathrm{b}\ (\mathrm{x}) \cap\ \mu\ \mathrm{c}(\mathrm{x})\big)$$

Defuzzification

$$z = \frac{\int z.\mu(z)dz}{\int \mu(z)dz}$$

Table 1. Rule Base

	Variable	Set	Domain	Universe Of Conversation
Input	Temperature	Cool	28, 29,5, 31	28-36°C
		Normal	30, 32, 34	
		Hot	33, 34,5, 36	
	Humidity	Dry	40, 47,5, 55	3-60 %
		Ideal	50, 60, 70	
		Wet	65, 72,5, 80	
	Ammonia	Low	0, 7,5, 15	0-40 ppm
		Currently	10, 20, 30	
		Tall	28, 34, 40	
Output	Fan DC	Low	0 20, 40	1-255%
		Normal	35, 122,5, 210	
		Fast	200, 227.5, 255	
	Lamp	Dim	1, 28, 55	1-255%
		Normal	52, 116, 180	
		Bright	170, 210, 250	
	Motor DC	Stop	0, 20, 40	0-255%
		Normal	35, 117.5, 200	
		Fast	190, 227.5, 255	

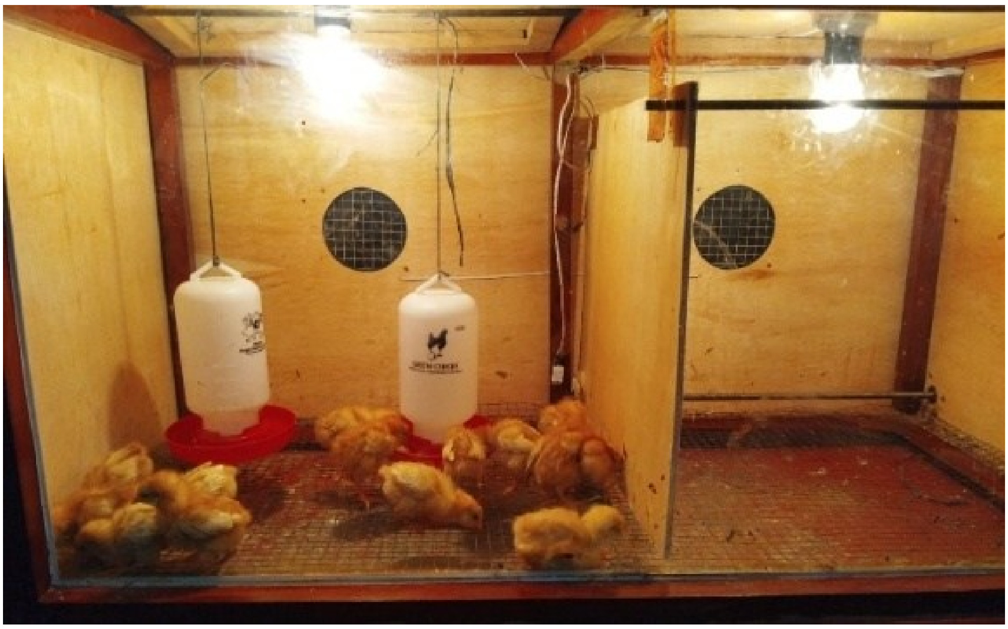

Fig. 6. Laying Hen Doc

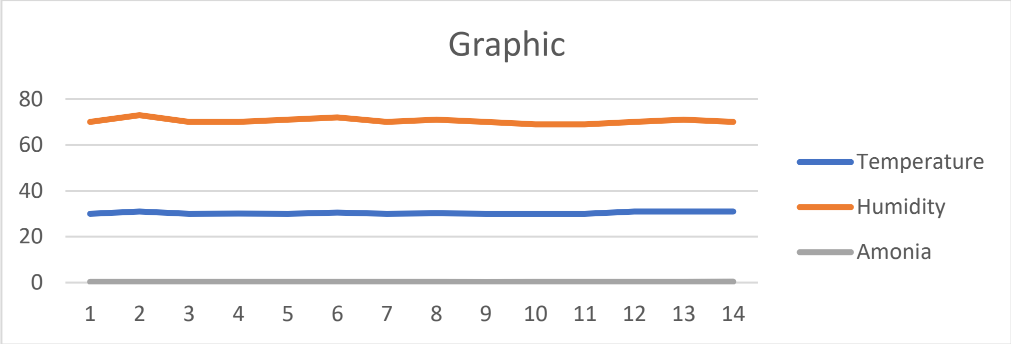

Fig. 7. Graphic Temperature, Humidity, Ammonia

Table 2. Temperature Data in The Chicken Incubator Room

Day	Temperature (°C)	Humidity (%)	Ammonia (ppm)
1	30	70	0.4
2	31	73	0.38
3	30	70	0.38
4	30,1	70	0.38
5	30	71	0.37
6	30, 5	72	0.36
7	30	70	0.36
8	30,3	71	0.36
9	30	70	0.32
10	30	69	0.36
11	30	69	0.36
12	31	70	0.37
13	31	71	0.36
14	31	70	0.42

4. Conclusion

Based on the design and testing, the developed automatic chick incubator successfully maintains temperature stability within a controlled range of 30°C - 34°C by automatically adjusting the incandescent lamp through dimming or switching. Humidity is also effectively regulated by modulating fan speed in response to sensor input. The system's manure conveyor is automatically activated when ammonia levels exceed 10 ppm, ensuring consistent cleanliness within the chamber. Furthermore, the automated partition movement helps reduce stress and improves feed accessibility as chicks grow, especially in space-limited environments.

This system addresses the initial objective of reducing DOC (Day-Old Chick) mortality and labour dependency by automating key environmental controls. The integration of temperature, humidity, and waste management replicates the conditions normally provided by a brooding hen. Initial trials indicate improved chick behaviour, lower stress indicators, and a cleaner hatching space, though precise mortality rate reductions require longer-term observation. Despite these successes, some limitations remain, including dependency on stable power supply and potential accuracy drift in gas sensors over time. Future improvements may include solar power integration, mobile app-based remote monitoring, and scalability for different capacities. In conclusion, this automatic incubator system offers a promising solution for small-scale poultry farmers, reducing operational workload and improving DOC survival conditions through low-cost, intelligent automation.

References

[1] A. L. Solano-Blanco, J. E. González, and A. L. Medaglia, "Production planning decisions in the broiler chicken supply chain with growth uncertainty," *Operations Research Perspectives*, vol. 10, p. 100273, 2023.

[2] A. Maigah and H. A. Latip, "Sustainable Socio-Economic Development of Women: A Blueprint from Vulnerability to Empowerment," *International Journal of Academic Reserach in Economics and Management Sciences*, vol. 12, no. 2, 2023.

[3] T. F. Ramukhithi, K. A. Nephawe, T. J. Mpofu, T. Raphulu, K. Munhuweyi, F. V. Ramukhithi, and B. Mtileni, “An assessment of economic sustainability and efficiency in small-scale broiler farms in limpopo province: a review,” *Sustainability*, vol. 15, no. 3, p. 2030, 2023.

[4] R. Putra, A. R. Tanjung, D. David, N. Renaldo, and C. Cecilia, “Chicken Egg Production in Aceh and Riau from 2009 to 2018 using Simple Linear Regression with SWOT Analysis Approach,” *Reflection: Education and Pedagogical Insights*, vol. 2, no. 1, pp. 15-19, 2024.

[5] C. Y. Wang, Y. J. Chen, and C. F. Chien, “Industry 3.5 to empower smart production for poultry farming and an empirical study for broiler live weight prediction,” *Computers & Industrial Engineering*, vol. 151, p. 106931, 2021.

[6] T. E. Farida, N. D. Hanafi, and M. R. Tafsin, “Comparative study of broiler chicken performance in closed house and conventional system in North Sumatera,” In *IOP Conference Series: Earth and Environmental Science*, vol. 977, no. 1, p. 012138, 2022.

[7] S. Syahrorini, A. Rifai, D. H. R. Saputra, and A. Ahfas, “Design smart chicken cage based on internet of things,” In *IOP Conference Series: Earth and Environmental Science*, vol. 519, no. 1, p. 012014, 2020.

[8] D. Hercog, T. Lerher, M. Truntič, and O. Težak, “Design and implementation of ESP32-based IoT devices,” *Sensors*, vol. 23, no. 15, p. 6739, 2023.

[9] S. B. Santoso, S. Adhy, N. Bahtiar and I. Waspada, "Development of The Smart Chicken Eggs Incubator Based on Internet of Things Using The Object Oriented Analysis and Design Method," *2020 4th International Conference on Informatics and Computational Sciences (ICICoS)*, pp. 1-6, 2020.

[10] K. R. Cheepati and N. Balal, “Solar Powered Thermoelectric Air Conditioning for Temperature Control in Poultry Incubators,” *Sustainability*, vol. 16, no. 11, p. 4832, 2024.

[11] R. O. Ojo, A. O. Ajayi, H. A. Owolabi, L. O. Oyedele, and L. A. Akanbi, “Internet of Things and Machine Learning techniques in poultry health and welfare management: A systematic literature review,” *Computers and Electronics in Agriculture*, vol. 200, p. 107266, 2022.

[12] L. Perdanasari, B. Etikasari, and D. L. Rukmi, “Control system for temperature, humidity, and ammonia levels in laying hens farms based on internet of things,” In *IOP Conference Series: Earth and Environmental Science*, vol. 1168, no. 1, p. 012053, 2023.

[13] A. A. Masriwilaga, T. A. J. M. Al-hadi, A. Subagja, and S. Septiana, “Monitoring system for broiler chicken farms based on Internet of Things (IoT),” *Telekontran: Jurnal Ilmiah Telekomunikasi, Kendali dan Elektronika Terapan*, vol. 7, no. 1, pp. 1-13, 2019.

[14] R. Budiarto, N. K. Gunawan, and B. A. Nugroho, “Smart chicken farming: Monitoring system for temperature, ammonia levels, feed in chicken farms,” In *IOP Conference Series: Materials Science and Engineering*, vol. 852, no. 1, p. 012175, 2020.

[15] E. F. Yogachi, V. M. Nasution, and G. Prakarsa, “Design and development of Fuzzy Logic Application Mamdani method in predicting the number of covid-19 positive cases in West Java,” In *IOP conference series: materials science and engineering*, vol. 1115, no. 1, p. 012031, 2021.

[16] A. K. Saputro, D. N. Purnamasari, Haryanto, M. Ulum, R. Alfita and M. Ibrahim, "Electrical Parameter Analysis on DLP 3D Printers using IoT (Internet of Things)," *2021 IEEE 7th Information Technology International Seminar (ITIS)*, pp. 1-5, 2021.

[17] A. Verma, S. Prakash, V. Srivastava, A. Kumar and S. C. Mukhopadhyay, "Sensing, Controlling, and IoT Infrastructure in Smart Building: A Review," in *IEEE Sensors Journal*, vol. 19, no. 20, pp. 9036-9046, 2019.

[18] A. A. Laghari, K. Wu, R. A. Laghari, M. Ali, and A. A. Khan, “A review and state of art of Internet of Things (IoT),” *Archives of Computational Methods in Engineering*, pp. 1-19, 2021.

[19] J. Astill, R. A. Dara, E. D. Fraser, B. Roberts, and S. Sharif, “Smart poultry management: Smart sensors, big data, and the internet of things,” *Computers and Electronics in Agriculture*, vol. 170, p. 105291, 2020.

[20] W. S. L. Nasution and P. Nusa, “UI/UX design web-based learning application using design thinking method,” *ARRUS Journal of Engineering and Technology*, vol. 1, no. 1, pp. 18-27, 2021.