



## Design and Implementation of Smart IoT-Based Broiler Room Controller

<sup>1</sup>Shamsu Sabo, <sup>2</sup>Abubakar Muhammad Umaru, <sup>3</sup>Jalo A. Ibrahim, <sup>4</sup>A. T. Sulaiman

<sup>1</sup>Department of Computer Science, National Open University of Nigeria, Fagge Study Center, Kano Nigeria

<sup>2</sup>Department of Computer Science, Faculty of Computing, Yusuf Maitama Sule University Kano, Nigeria

<sup>3,4</sup>Department of Computer Engineering, Kaduna Polytechnic, Kaduna, Kaduna State, Nigeria

### ABSTRACT

*This paper introduces an innovative Internet of Things (IoT) Smart Broiler Room Controller, which combines the ESP32 microcontroller with the Arduino platform to meet the evolving needs of the poultry industry. Positioned at the intersection of agricultural advancement and IoT technology, this system exemplifies IoT's transformative potential in broiler farming. The controller offers precise control over the broiler room's fan, heater, and lighting systems, dynamically responding to changes in ambient light, temperature, and humidity based on predetermined targets. Operating on a tailored seven-week cycle, it adapts to the broilers' developmental stages, which significantly reduces unnecessary power consumption compared to traditional fixed-threshold systems. The system's effectiveness is demonstrated through improved energy efficiency and reduced operational costs. Manual control is facilitated through an intuitive IoT interface, while DHT11/LDR sensors and the ESP32 microcontroller enable real-time data visualization on an LCD. This development not only advances agricultural practices but also integrates cutting-edge IoT technology, offering a substantial improvement in managing environmental conditions within broiler rooms.*

### ARTICLE INFO

#### Article History

Received: January, 2024

Received in revised form: March, 2024

Accepted: June, 2024

Published online: June, 2024

### KEYWORDS

Smart Broiler Room Controller, DHT11 Sensor, LDR Sensor, IoT Integration, ESP32 Microcontroller. Actuator Management, Manual/Automatic Control.

### INTRODUCTION

The traditional approaches to controlling temperature, humidity, and lighting in broiler production pose serious technological challenges in the ever-changing poultry industry. In addition to falling short of the requirements of contemporary broiler farming, relying on antiquated automation systems and manual controls also results in needless expenses. This gap highlights the urgent need for a state-of-the-art, highly technologically advanced control system that can optimize resource utilization and precisely regulate environmental factors, thereby ushering in a new era of innovation in broiler production.

Severe temperature swings are a direct threat to poultry health in the delicate balance between heat and cold stress (Enriko et al., 2021). When birds are unable to control their body temperature, heat stress becomes a dangerous enemy that can have fatal consequences if the

birds' ability to dissipate heat is impaired. On the other hand, cold stress is less obvious but nonetheless impairs critical physiological processes in chickens, leading to dire consequences like impaired digestion, decreased immunity, and constricted circulation.

In this story, careful environmental management comes out on top, providing a perfect home for three-week-old broilers between 20°C and 25°C, along with a healthy relative humidity range of 50% to 70% and the right amount of light. Older broilers and laying hens, who thrive in their designated temperature ranges of 26°C to 27°C and 18°C to 23.9°C, respectively, are the next in this delicate dance between life and environment. Particularly, sensitive chicks require carefully controlled temperatures of 32°C to 35°C for the first week of life, lowering by about 3°C every week (Bhawa et al., 2023).

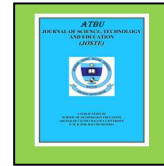
The tale which illustrates the symbiotic relationship between life and its surroundings in

Corresponding author: Abubakar Muhammad Umaru

✉ [amumar@yahoo.com](mailto:amumar@yahoo.com)

Department of Computer Science, Faculty of Computing Yusuf Maitama Sule University, Kano.

© 2024. Faculty of Technology Education. ATBU Bauchi. All rights reserved



broiler farming, goes beyond academic discourse. It emphasizes how important environmental control is—not just as a tool, but as the lifeline that decides what happens to broilers and how poultry farming will develop in the future.

### STATEMENT OF THE PROBLEM

The efficiency and sustainability of environmental control systems in poultry farms are critical for minimizing operational costs and energy consumption. Traditional methods frequently rely on fixed temperature and humidity thresholds, resulting in constant operation of cooling and heating systems regardless of the broilers' changing requirements. While some modern systems include cooling or heating controls, they typically rely on static thresholds or lack comprehensive adaptability, such as precise dynamic scheduling for temperature and humidity and lighting management. This study aims to address these limitations by developing an IoT-based system that combines dynamic temperature and humidity schedules with cooling and heating controls, and lighting management. The goal is to determine whether this advanced system significantly improves power consumption and overall sustainability when compared to traditional and some modern methods. The study will specifically investigate whether incorporating energy-efficient solutions and advanced control algorithms reduces power consumption significantly while also improving environmental management efficiency in poultry farming.

### Objectives of the Study

The study has the following objectives to:

1. Implement an IoT-based system for comprehensive environmental monitoring and automated control of critical factors such as temperature, humidity, and lighting on poultry farms. This system will automate the operation of fans, heaters, and lighting, increasing operational efficiency and lowering costs.
2. Reduce the power consumption of environmental control systems, design and integrate energy-efficient solutions. Tailored lighting solutions and advanced control algorithms will be developed to ensure long-

term and cost-effective poultry house operations.

### Research Questions

The study aimed to answer the following questions:

1. How does implementing an IoT-based environmental monitoring system improve the efficiency and cost-effectiveness of temperature, humidity, and lighting control in poultry farms?
2. How does incorporating energy-efficient solutions and advanced control algorithms affect power consumption and overall sustainability in poultry house environmental control systems?

### Null Hypotheses

The following null hypotheses are set to be tested:

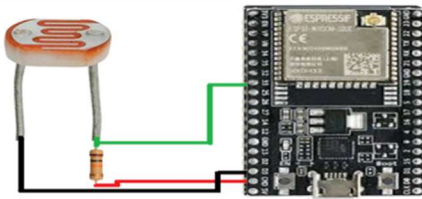
**HO1:** Designing and implementing IoT-based environmental monitoring and automated control systems does not significantly improve temperature, humidity, and illumination management in poultry farms when compared to traditional methods. Furthermore, these systems do not lead to a significant reduction in operational costs or an increase in efficiency.

**HO2:** When compared to traditional methods, using energy-efficient solutions and advanced control algorithms does not result in a significant reduction in power consumption or contribute to more sustainable and cost-effective operations in environmental control systems on poultry farms.

### METHODOLOGY

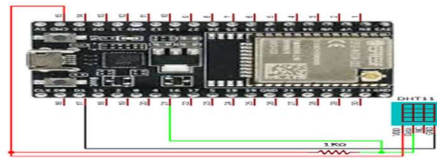
#### Hardware Implementation

The ESP32 microcontroller acts as the main processing unit in the broiler room control system that runs on a 12V battery and coordinates the actions of numerous sensors and actuators. The ESP32 communicates with the LDR (Light Dependent Resistor) sensor via analog



**Figure 1: LDR Interfaced with ESP32**

A digital protocol is used for communication between the ESP32 and the DHT11 sensor, which measures humidity and temperature. It offers up-to-date environmental information that is essential for preserving ideal circumstances in the broiler room.

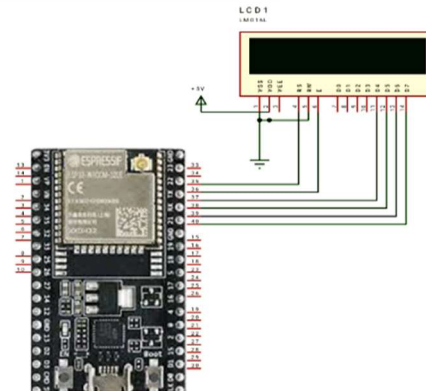


**Figure 2: DHT11 Interfaced with ESP32**

An LM7805 regulator integrated circuit is used to power the ESP32 and other components for voltage regulation and stability, guaranteeing steady operation even in the event of variations in the battery's input voltage.

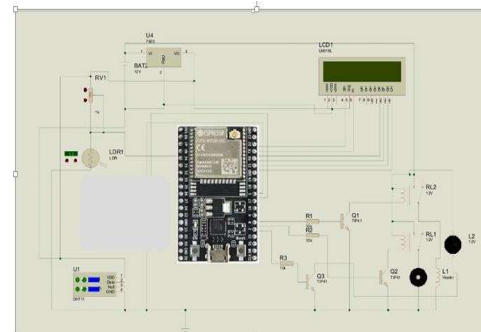
The ESP32 in the Control Unit controls the environmental parameters based on predetermined thresholds. This unit has relays to control a range of appliances, such as heaters and fans, resistors, and a BC547 transistor to control motor speed. The potentiometer gives precise control over light-dependent actions by adjusting the sensitivity of the LDR.

Finally, the Output Unit has a 16\*2 LCD (Liquid Crystal Display) that functions as a user interface and shows vital data like system status, humidity, and temperature. The ESP32 controls how this data is displayed, providing users with up-to-date information about the conditions in the broiler room. Furthermore, users are able to monitor and control the ESP32 system remotely thanks to its web server interface. In order to ensure smooth operation and user-friendly interaction, connectors and interface parts help integrate the LCD and other components seamlessly.



**Figure 4: 16\*2 LCD interfaced with ESP32**

The system effectively collects environmental data, processes it with the ESP32, regulates conditions, and shows relevant information to users via the LCD interface and remote access features by combining these input, control, and output units.



**Figure 4: Circuit Diagram representing the interconnected components within the system**

#### Development of Software Frameworks:

The software architecture was strengthened by integrating multiple libraries, enabling network connectivity, asynchronous communication, sensor interfacing, LCD control, and time-based operations. It was operational within the Arduino IDE using C++. A well-written codebase coordinated essential features like web server handlers, WiFi setup, and a strong control logic system for environmental regulation. A

sample of the system's code can be seen in the code snippet below:

```
#include <WiFi.h>
#include <AsyncTCP.h>
#include <ESPAsyncWebServer.h>
#include <LiquidCrystal.h>
#include <DHT.h>
#include <EEPROM.h>
#include <TimeLib.h>

const char* ssid = "U.kairi";
const char* password = "12345678";

// Set temperature and humidity schedule for growing broilers
const int temp_schedule[] = {32, 30, 28, 26, 24, 22, 20};
const int humidity_schedule[] = {60, 55, 50, 45, 40, 35, 30};

// Functions for web server handling, data transmission, and manual device control

void loop() {
    // Environmental analysis and sensor readings

    // Control logic for fans, heaters, and light based on conditions
    if (manualFanControl || manualHeaterControl) {
        // Manual control is active, maintaining current states.
    } else {
        // Automatic control based on predefined conditions
        // Adjust fan, heater, and light accordingly
        // ...
    }

    // Manual control for light
    // ...
}
```

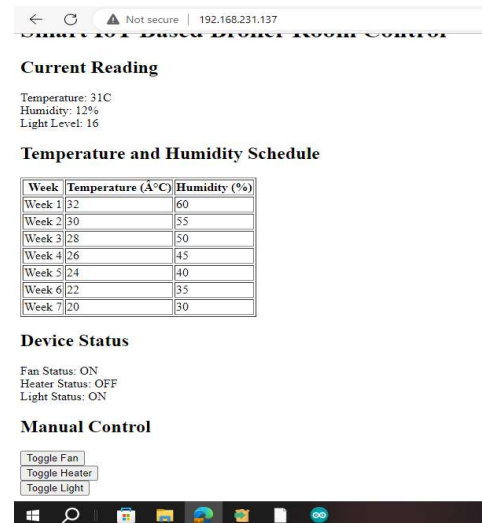
### System Functionality and Demonstration:

The system demonstrated its ability to regulate itself on its own by turning on the heater when the temperature fell below the threshold and turning on the fan when the temperature rose above it. Additionally, it changed the lighting, activating it when ambient levels dropped below

the predetermined threshold of 500 lux and turning it off when they rose above. In addition, the system ran according to a schedule, changing the humidity and temperature on a weekly basis. For each successive week, the temperature was specifically set at 32°C, 30°C, 28°C, 26°C, 24°C, 22°C, and 20°C, and the humidity levels were changed to 65%, 60%, 55%, 50%, 45%, 40%, and 35%, correspondingly (Enriko et al., 2021). With the system's adaptation, the ideal conditions for broiler growth were guaranteed.



**Figure 5: Illustration of the fully assembled system within the broiler room environment.**



**Figure 6: Screenshot of the web interface enabling remote monitoring and manual control.**

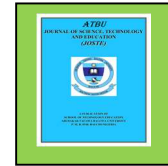
Throughout the seven-week cycle, the system gave users total visibility and control over

Corresponding author: Abubakar Muhammad Umaru

✉ [amumaru@yahoo.com](mailto:amumaru@yahoo.com)

Department of Computer Science, Faculty of Computing Yusuf Maitama Sule University, Kano.

© 2024. Faculty of Technology Education. ATBU Bauchi. All rights reserved



the environmental conditions of the broiler room through the web interface and the LC

ensure proper lighting management.

**Data Collection Procedure**

The data collection phase was specifically designed to last seven weeks. The process entailed collecting data on two specific days per week, with hourly readings taken to provide a comprehensive dataset. DHT11 sensors are used to measure temperature and humidity. These sensors were strategically located throughout the broiler room to collect representative data of the environment. The web server interface enabled real-time monitoring and control, with sensor readings automatically recorded.

**Data Analysis Procedure**

Sensor readings were compared to predefined reference standards to determine system accuracy. Weekly average temperatures and humidity levels, and comparisons of various sensor readings, were presented in table and graphical format. Furthermore, the system's lighting control performance was assessed by monitoring its operation at a 500-lux threshold to

**RESULTS**

**Research Question One:** how does implementing an IoT-based environmental monitoring system improve the efficiency and cost-effectiveness of temperature, humidity, and lighting control in poultry farms?

In response to the above question. The IoT-based system developed for this study includes sensors like the DHT11 for temperature and humidity monitoring and an LDR (Light Dependent Resistor) for light level measurement. These sensors are linked to a microcontroller, which automatically controls devices like fans, heaters, and lights based on predetermined environmental conditions. To ensure the DHT11 sensor's accuracy, the data was validated against reference standards using a thermometer and hygrometer.

The average temperature and humidity readings from the DHT11 sensor were compared to those of the reference standards. The results showed minimal differences, confirming the DHT11 sensor's reliability.

**Table 1: Comparison of Temperature and Humidity Measurements**

| Week           | DHT11 (°C)    | THERMOMET ER (°C) | DHT11 (%)     | HYGROMETER (%) |
|----------------|---------------|-------------------|---------------|----------------|
| Week 1         | 30.58         | 30.33             | 38            | 36             |
| Week 2         | 29.54         | 29.32             | 45.38         | 44.38          |
| Week 3         | 30.21         | 30.23             | 37.67         | 36.42          |
| Week 4         | 30.46         | 30.33             | 38.5          | 37.13          |
| Week 5         | 30.38         | 30.13             | 39.29         | 37.88          |
| Week 6         | 29.25         | 28.99             | 40.33         | 38.79          |
| Week 7         | 29.54         | 29.24             | 40.46         | 39             |
| <b>Average</b> | <b>29.994</b> | <b>29.749</b>     | <b>39.947</b> | <b>38.515</b>  |

The DHT11 sensor recorded an average temperature of 29.994°C, which was 0.245°C higher than the thermometer's average of 29.749°C. The DHT11 sensor recorded an average humidity of 39.947%, 1.432% higher than the hygrometer's average humidity of 38.515%. These minor differences suggest that the DHT11

sensor produces accurate data that closely matches the reference standards.

The IoT system automates the control of temperature, humidity, and lighting, resulting in more consistent and precise management. This automation eliminates the need for manual adjustments, lowering labor costs and reducing human errors. Additionally, the system optimizes

Corresponding author: Abubakar Muhammad Umaru

✉ [amumaru@yahoo.com](mailto:amumaru@yahoo.com)

Department of Computer Science, Faculty of Computing Yusuf Maitama Sule University, Kano.

© 2024. Faculty of Technology Education. ATBU Bauchi. All rights reserved

the use of fans, heaters, and lights, reducing energy waste and operational costs.

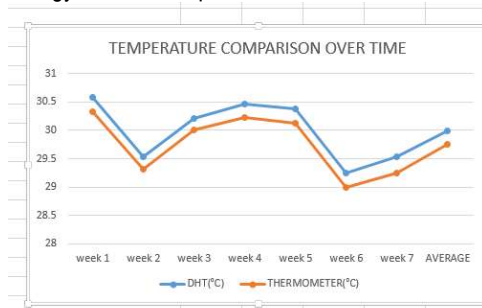


Figure 1: Temperature Comparison over Time

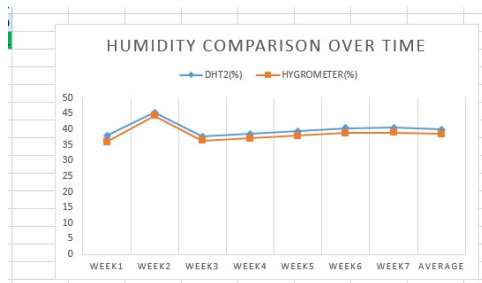


Figure 2: Humidity Comparison over Time

The graphs in Figures 1 and 2 illustrate the comparison of temperature and humidity readings between the DHT11 sensor and the reference instruments over the study period. The graphs confirm the sensor's reliability and the system's effectiveness in maintaining the desired environmental conditions.

The LDR sensor controls the lighting, measuring light levels and turning them off when they fall below 500 lux. Although detailed data for light level validation is not provided, the web interface shows lights being turned off as needed, demonstrating the control's effectiveness.

Overall, the IoT-based environmental monitoring system improves the efficiency and cost-effectiveness of controlling temperature, humidity, and lighting in poultry farms. Accurate and reliable data from sensors such as the DHT11, when combined with automated control mechanisms, ensures optimal environmental conditions, improves poultry health and growth, and lowers operational costs through energy

savings and reduced labor requirements. The implementation of IoT-based systems is a critical step toward modernizing poultry farming practices, resulting in more sustainable and cost-effective operations.

**Null Hypothesis One:** Designing and implementing IoT-based environmental monitoring and automated control systems does not significantly improve temperature, humidity, and illumination management in poultry farms when compared to traditional methods. Furthermore, these systems do not lead to a significant reduction in operational costs or an increase in efficiency.

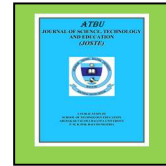
Testing the hypothesis that "designing and implementing IoT-based environmental monitoring and automated control systems does not significantly improve temperature, humidity, and illumination management in poultry farms when compared to traditional methods" necessitates a closer examination of the data and results from the IoT-based system developed in this study. The system, which uses sensors such as the DHT11 for temperature and humidity and an LDR for light measurement, showed significant improvements in maintaining optimal environmental conditions. The temperature and humidity readings from the DHT11 sensor were almost identical to those from the reference thermometer and hygrometer, confirming the system's accuracy. Over a seven-week period, automated control of environmental factors such as temperature, humidity, and lighting ensured precision while also reducing energy waste and labor costs by eliminating the need for manual adjustments. The data show that the system successfully optimized resource usage, resulting in more sustainable and cost-effective operations. These findings directly contradict the null hypothesis, the findings conclusively show that IoT-based environmental control systems provide significant improvements in managing environmental conditions in poultry farms, resulting in increased efficiency and lower operational costs when compared to traditional methods. This is supported by the analysis of studies reviewed in the literature, which include

Corresponding author: Abubakar Muhammad Umaru

✉ [amumaru@yahoo.com](mailto:amumaru@yahoo.com)

Department of Computer Science, Faculty of Computing Yusuf Maitama Sule University, Kano.

© 2024. Faculty of Technology Education. ATBU Bauchi. All rights reserved



research on both traditional and modern approaches, highlighting the superiority of IoT-based solutions. Hence, the hypothesis is conclusively rejected.

**Research Question Two:** how does incorporating energy-efficient solutions and advanced control algorithms affect power consumption and overall sustainability in poultry house environmental control systems?

Many studies, including those reviewed in the literature, kept temperature and humidity thresholds constant throughout the study, regardless of the broilers' specific needs at various stages of development. This approach resulted in increased energy consumption and unnecessary activation of cooling and heating systems. For example, (Widhiada, 2018)'s baby incubator control system was accurate but power-consuming, whereas (Sipani et al., 2017)'s temperature and humidity control system was heavily reliant on internet connectivity, potentially limiting its use in areas with poor infrastructure. Systems that focused on fan speed control [(Rao et al., 2018), room heat control (Murtala Zungeru et al., 2018), and IoT-based temperature and humidity control (Barik, 2019) varying degrees of effectiveness but frequently had limitations in terms of scalability, connectivity, or functionality. For example, (Sonawane et al., 2019) created a low-cost monitoring system that lacked advanced features such as temperature scheduling. Similarly, systems designed for composting (Sabale & Bute, 2020) and temperature control in enclosed areas (Nyiekaa & Francis, 2021) provided basic functionality but did not address more complex needs.

Recent innovations, including the PID-controlled smart poultry farm system by (Enriko et al., 2021), the electronic jacket for weather control by (Brad & Brad, 2021), and the mobile application interface by ((Castro et al., 2022), show progress but may face challenges with scalability and connectivity. (Sasirekha et al., 2023) poultry house monitoring system and (Susanto et al., 2023) IoT-based temperature and humidity monitoring show promise, but they may face

infrastructure limitations and a lack of integrated scheduling.

In contrast, the device developed in this study introduces a more precise control mechanism by creating distinct temperature and humidity schedules for each week of a seven-week cycle based on the broilers' specific requirements. This precise adjustment ensures that environmental conditions are perfectly matched to the broilers' developmental stage, increasing energy efficiency by reducing unnecessary device operation. Furthermore, the inclusion of both cooling and heating controls, as opposed to systems that only include one type, provides greater flexibility and precision in controlling the broiler room environment. This targeted approach reduces power consumption and improves overall sustainability by dynamically adjusting environmental parameters to meet the broilers' specific needs throughout their growth period.

**Null Hypothesis Two:** When compared to traditional methods, using energy-efficient solutions and advanced control algorithms does not result in a significant reduction in power consumption or contribute to more sustainable and cost-effective operations in environmental control systems on poultry farms.

The hypothesis suggested that implementing energy-efficient solutions and advanced control algorithms would have little impact on power consumption and would result in more sustainable and cost-effective operations than traditional methods. The results of this study call into question that hypothesis.

Traditional methods and some modern systems frequently rely on fixed temperature and humidity thresholds, resulting in the continuous operation of cooling or heating systems regardless of the broilers' actual requirements. These systems lack adaptability, resulting in increased power consumption and operational costs due to unnecessary device activation. Furthermore, some modern systems may only include cooling



or heating controls, limiting the versatility of integrated solutions.

In contrast, the IoT-based system developed in this study addresses these issues by using dynamic temperature and humidity schedules that are tailored to each week of the broiler's growth cycle. This method ensures that cooling and heating devices are only activated when necessary, resulting in significant power savings. In addition, the system includes both cooling and heating controls, as opposed to some systems that only include one type of control, and lighting control. This comprehensive approach improves energy efficiency, lowers operational costs, and promotes sustainability by reducing unnecessary energy consumption.

The findings clearly demonstrate that the advanced control algorithms and energy-efficient solutions used in the developed system outperform traditional and some contemporary methods. Thus, the hypothesis is refuted, showing that these modern Solutions are effective in improving environmental management, reducing power consumption, and promoting more sustainable poultry farming practices.

## DISCUSSION OF FINDINGS

The findings of this study highlight the significant advantages of implementing an IoT-based environmental control system designed to optimize temperature, humidity, and lighting management in poultry farms. The study aimed to create a system that not only improves operational efficiency but also reduces power consumption by utilizing advanced control algorithms and energy-efficient solutions.

Traditional environmental control systems, including some modern iterations, typically use fixed temperature and humidity thresholds throughout the broiler's growth cycle. This approach frequently results in the continuous operation of heating and cooling systems, regardless of the broilers' actual environmental needs at each stage. As a result of these systems' lack of adaptability, they consume excessive amounts of power and incur higher operational costs.

In contrast, the IoT-based system developed in this study overcomes these limitations by introducing dynamic temperature and humidity schedules that are tailored to the broilers' needs for each week of their growth cycle. This tailored approach ensures that cooling and heating devices only activate when necessary, resulting in a significant reduction in power consumption when compared to systems with static thresholds.

Furthermore, the system's integration of cooling and heating controls, as well as lighting management, improves its efficiency and flexibility. Unlike traditional systems, which may only provide one type of control, the developed system offers a comprehensive solution for optimizing energy use across multiple environmental parameters. This reduces environmental impact and promotes more sustainable poultry farming practices by better aligning energy consumption with the broilers' specific needs.

Overall, the research shows that incorporating energy-efficient solutions and advanced control algorithms improves environmental management in poultry farms while significantly lowering power consumption and operational costs. This approach effectively addresses the study's objectives by providing a more efficient and sustainable alternative to traditional and some contemporary environmental control systems.

## CONCLUSION

This study looked into the efficacy of incorporating energy-efficient solutions and advanced control algorithms into environmental control systems for poultry farms to improve operational efficiency, reduce power consumption, and increase sustainability. The study aimed to create and implement an Internet of Things-based system for comprehensive temperature, humidity, and lighting monitoring and control.

The findings show that traditional environmental control methods, as well as some modern systems, frequently use fixed temperature and humidity thresholds throughout the broiler's growth cycle. These methods result in the





continuous operation of cooling and heating systems, regardless of the broilers' actual needs, resulting in excessive energy consumption and higher operational costs. Modern systems that only incorporate cooling or heating controls and also use fixed thresholds exhibit similar inefficiencies due to their limited adaptability and lack of precision.

In contrast, the IoT-based system developed in this study employs dynamic control mechanisms and customized schedules for temperature, humidity, and lighting. This method ensures that cooling and heating devices are only activated when necessary, in accordance with the broilers' specific requirements at each stage of their growth cycle. The integration of cooling and heating controls, as well as precise lighting management, increases the system's flexibility and efficiency.

The research shows that the advanced control algorithms and energy-efficient solutions used in the IoT-based system outperform both traditional and some modern methods. The system saves power and money by reducing unnecessary device operation and optimizing energy use. Furthermore, precise control over environmental factors promotes more sustainable poultry farming practices.

In conclusion, the study effectively refutes the hypothesis that energy-efficient solutions and advanced control algorithms will not provide significant benefits when compared to traditional and some modern control methods. The results highlight the benefits of adopting advanced IoT-based systems in poultry farming, emphasizing their potential for improved efficiency, reduced energy consumption, and enhanced sustainability.

## RECOMMENDATIONS

Based on the findings of this study, the followings recommendations were made;

- i. Poultry farmers should be encouraged to use IoT-based environmental control systems that include dynamic temperature and humidity schedules and integrated lighting control. The results show that such systems

significantly improve environmental management efficiency and operational sustainability when compared to traditional methods.

- ii. Professional organizations such as agricultural ministries and poultry associations should organize training programs and workshops to educate farmers about the advantages of advanced IoT-based systems. To improve environmental conditions in poultry farming, emphasis should be placed on the use of energy-efficient solutions and advanced control algorithms.

## LIMITATIONS OF THE STUDY

The study had the following limitations:

- I. The study's reliance on reliable internet and power may not be consistent across all poultry farms, limiting the system's deployment and generalizability.
- II. Using an IoT system requires technical expertise. Users' familiarity with technology can vary, influencing the system's implementation and overall effectiveness.

## SUGGESTIONS FOR FURTHER STUDIES.

The followings suggestions are put forward for further studies:

1. Consider integrating the IoT-based environmental control system with other farm management systems, such as feed management and health monitoring. This could provide a more comprehensive approach to farm management while improving overall operational efficiency.
2. Examine the effectiveness of the IoT-based environmental control system across a broader range of environmental conditions and poultry breeds. This could include testing in various climate zones and with different types of poultry to determine the system's adaptability and performance in a variety of settings.

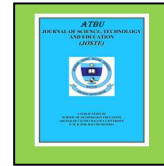
---

Corresponding author: Abubakar Muhammad Umaru

✉ [amumaru@yahoo.com](mailto:amumaru@yahoo.com)

Department of Computer Science, Faculty of Computing Yusuf Maitama Sule University, Kano.

© 2024. Faculty of Technology Education. ATBU Bauchi. All rights reserved



## REFERENCES

- Barik, L. (2019). IoT based temperature and humidity controlling using Arduino and Raspberry Pi. *International Journal of Advanced Computer Science and Applications (IJACSA)*, 10(9). <http://www.ijacsa.thesai.org>
- Bhawa, S., Morêki, J. C., & Machete, J. B. (2023). Poultry management strategies to alleviate heat stress in hot climates: A review. *Journal of World's Poultry Research*, 13(1), 1–19. <https://doi.org/10.36380/jwpr.2023.1>
- Brad, A., & Brad, M. (2021). Development of a smart clothing product using an Arduino platform. *International Journal of Advanced Statistics and IT&C for Economics and Life Sciences*, 11(1), 38–61. <https://doi.org/10.2478/ijasitels-2021-0002>
- Castro, C. M. M., Mestria, A., & Mestria, M. (2022). Temperature control system using mobile application interface. *European Journal of Formal Sciences and Engineering*.
- Enriko, A., Putra, R. A., & Estananto. (2021). Automatic temperature control system on smart poultry farm using PID method. *Green Intelligent Systems and Applications*, 1(1), 37–43. <https://doi.org/10.53623/gisa.v1i1.40>
- Murtala Zungeru, A., Mangwala, M., Chuma, J., Gaebolae, B., & Basutli, B. (2018). Design and simulation of an automatic room heater control system. *Heliyon*, 4, e00655. <https://doi.org/10.1016/j.heliyon.2018>
- Nyiekaa, E. A., & Francis, C. A. (2021). Design and construction of an automatic temperature control system. *Journal of Scientific and Engineering Research*, 84(6), 84–91. <http://www.jsaer.com>
- Rao, M. N., Lalitha Devi, P., Mahitha, K. K., & Prem Kumar, K. (2018). Temperature-based fan speed control and observing utilizing Arduino. *International Journal of Engineering & Technology*, 7(1). <http://www.sciencepubco.com/index.php/IJET>
- Sabale, R. S., & Bute, V. (2020). Microcontroller-based temperature controller system. *International Research Journal of Engineering and Technology*. <http://www.irjet.net>
- Sasirekha, R., Kaviya, R., Saranya, G., Mohamed, A., & Iroda, U. (2023). Smart poultry house monitoring system using IoT. *E3S Web of Conferences*, 399. <https://doi.org/10.1051/e3sconf/202339904055>
- Sipani, J. P., Patel, R. H., Upadhyaya, T., & Patel, V. T. (2017). Temperature & humidity monitoring & control system based on Arduino and SIM900A GSM shield. *International Journal of Electrical, Electronics and Data Communication*, 5(5). <http://iraj.in>
- Sonawane, R. N., Ghule, A. S., Bowlekar, A. P., & Zakane, A. H. (2019). Design and development of temperature and humidity monitoring system. *Agricultural Science Digest - A Research Journal*. <https://doi.org/10.18805/ag.d-4893>
- Susanto, A., Ardi Agung, A. R., Ibrahim, M., Dwi Sugiarto, T., Yuswanto, A., & Wibowo, B. (2023). Design of a temperature and humidity monitoring system in broiler farms using Internet of Things-based Thingspeak. *Jurnal Komputer Dan Elektro Sains*, 1(1), 9–13. <https://doi.org/10.58291/komets.v1i1.92>
- Widhiada, W. (2018). Temperature distribution control for baby incubator system using Arduino AT Mega 2560.

Corresponding author: Abubakar Muhammad Umaru

✉ [amumaru@yahoo.com](mailto:amumaru@yahoo.com)

Department of Computer Science, Faculty of Computing Yusuf Maitama Sule University, Kano.

© 2024. Faculty of Technology Education. ATBU Bauchi. All rights reserved