IoT-Based Smart Environmental Management System for Enhanced Broiler Production

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ABSTRACT

The vital food production industry of broiler farming continues to confront three main difficulties involving inefficient resource utilization and disease spread together with unfavorable growth conditions, poultry production using Internet of Things integrates technology to generate substantial yield enhancements by optimizing environmental standards and controlling feed distribution and water delivery coupled with medical surveillance systems. The paper proposes an IoT-based environmental control system that employs economical universal components for broiler houses. The implemented system utilizes a DHT22 sensor to run continuous temperature and humidity monitoring, which ensures correct broiler climate conditions for proper development, as well as the system operates water supply functions through a servo motor and controls lighting with NeoPixel LEDs to adjust bird circadian rhythms toward improved well-being. The system uses an ESP32 microcontroller as its main processing component, providing quick data transfer capabilities and remote interface features. The software platform utilizes Wokwi for IoT simulation while Node-RED serves to build an interactive dashboard that farmers can use to monitor and modify system parameters. The system's experimental data shows its capability to preserve suitable environmental parameters while cutting down maintenance needs and boosting broiler developmental rates. The paper established through this investigation that IoT-based smart farming solutions show promise for enhanced productivity together with reduced operative expenses and improved sustainable poultry industry methods.

Keywords: Broiler yield optimization, Environmental monitoring, Smart farming, ESP32, DHT22 sensor, Automated water control, Wokwi simulation, Node-RED.

INTRODUCTION

The global food production system relies heavily on broiler farming, through which significant quantities of worldwide poultry meat production take place. Rising poultry product demand generates strong pressure on farmers to boost their operational efficiency in a manner that sustains wholesome animal conditions (Abbas *et al.,* 2025). The broiler industry struggles with several problems that stem from inefficient resource management along with diseases and environmental changes and variable growth numbers. These issues result in increased production expenses and lower production output and greater death rates, which affect business profitability and sustainability measurements (Thilakarathne *et al.,* 2025).

Real-time monitoring and automation control in broiler farms can be achieved through the innovative IoT (Internet of Things) technology solutions developed recently. IoT-based systems make use of sensor-actuator-cloud analytics networks that acquire environmental data regarding temperature, humidity, ammonia levels, and ventilation measurements. Through automated feeding integrated with watering systems, the farmer can increase resource efficiency while reducing waste and providing consistent nutritional care to the poultry birds (Kolikipogu *et al*., 2025).

This paper proposes the design and implementation of an IoT-based platform for monitoring and controlling environmental conditions in broiler houses. A cost-effective implementation utilizes microcontrollers together with temperature and humidity sensors and smart actuators as well as software tools that deliver real-time visualization and automated control systems. The system delivers continuous monitoring combined with intelligent control features to boost broiler growth conditions and minimize disease risks while maximizing the efficiency of the farm operations.

The remainder of this paper is structured as follows: Section 2 discusses related work and existing solutions in IoT-based poultry farming. Section 3 describes the materials and methods, including hardware and software components. Section 4 covers implementation details. Section 5 shows the experimental results and findings discussion. Finally, Section 6 presents conclusions and future research directions.

Related work

The integration of Internet of Things (IoT) technologies in poultry farming has improved animal welfare recently. This section reviews the existing literature in IoT-based poultry farming.

Lifwarda *et al.* (2025) proposed an IoT-based monitoring and control system for temperature and ammonia gas levels in chicken farms. The system is designed to enhance poultry health, improve farm productivity, and minimize pollution risks associated with ammonia gas (NH_3) (Lifwarda, *et al*., 2025).

Widayanto and Aji (2025) proposed IoT-based system for broiler feed monitoring application in Indonesia that can monitor feed stocks in realtime, set automatic feeding schedules, and analyze feed consumption data to increase efficiency, accuracy, and overall productivity. Interim results show that the feed monitoring application with IoT technology is able to provide accurate and detailed information in real-time, reduce human error, and increase operational efficiency significantly.

Ramadhani *et al.,* (2025) proposed an automatic sensor monitoring system for broiler chickens using the Internet of Things (IoT) and Telegram bots as a communication platform. This system is designed to improve the efficiency of chicken farming by reducing the need for manual intervention and providing more accurate environmental monitoring. The system used the DHT11 sensor to measure temperature and humidity in real time, and data is sent to the ESP32 microcontroller, which regulates the temperature to achieve ideal conditions. The Telegram bot allows farmers to monitor the system remotely and receive notifications about the temperature of the cage and other conditions.

Sabo *et al.* (2025) proposed an IoT-based smart broiler room control system in order to monitor and regulate critical environmental parameters such as temperature and humidity to ensure optimal conditions for broiler growth. The system integrates an ESP32 microcontroller with the Arduino platform and utilizes sensors like the DHT11 and LDR to dynamically adjust environmental controls, including fans, heaters, and lights, based on real-time data.

Johar *et al.* (2024) proposed an IoT-based system to enhance the efficiency and productivity of poultry farming, particularly for small and medium-scale farmers who still rely on traditional methods. The proposed system enables real-time monitoring and control of these environmental parameters (temperature, humidity, and ammonia gas levels in chicken coops), ensuring optimal conditions for chicken growth and reducing the risk of disease. The system used an ESP8266 microcontroller, a Raspberry Pi 4, and a DHT11 sensor to monitor environmental conditions. The results show the performance and effectiveness of the IoT-based smart broiler room controller in maintaining optimal environmental conditions for broiler growth. The system was evaluated over a seven-week period.

The reviewed studies highlight the potential of IoT technologies in optimizing broiler growth in poultry farming. However, existing systems often focus on monitoring the environmental conditions in broiler houses without providing a comprehensive solution as well as lack intelligent data-driven decision support.

This paper addresses this gap by proposing an IoT-based smart environmental monitoring and control system that integrates real-time environmental conditions monitoring and water control as well as lighting control.

MATERIALS AND METHODS

This section presents the hardware and software components for developing the proposed system as shown below:

Hardware components

The proposed system consists of the following physical components:

1. DHT22 Sensor

This sensor is used to measure the temperature and humidity in the broiler house and provides accurate readings with a temperature range of -20°C to 60°C and a humidity range of 0–100%. Additionally, the sensor is connected to the ESP32 microcontroller for data transmission.

2. Servo Motor

This actuator is used for the opening and closing of water valves based on real-time humidity data in order to ensure optimal water availability.

3. ESP32 Microcontroller

This is a Wi-Fi module used to act as the central processing unit, connecting all sensors and actuators, and it provides Wi-Fi connectivity for data transmission to the analytical Platform in order to remote monitoring.

4. NeoPixel LEDs

Used for smart lighting control to simulate natural daylight cycles, and adjusts brightness and color temperature based on the time of day and broiler growth stage.

5. LED Indicators

Provide visual feedback for system status.

The following table (Table 1) demonstrate the physical components and their tasks in the proposed system:

Table 1. Demonstrates the physical components and their task

Components	Task
DHT22 Sensor (Mutaqi *et al.,* 2025)	used to measure the temperature and humidity in the broiler house.
Servo Motor (Zhang *et al.,* 2025)	Used to control the opening and closing of water valves
ESP32 Microcontroller (Nguyen *et al.,* 2025)	Acts as the central processing unit, connecting all sensors and actuators.
NeoPixel LEDs (Mayani, M. G. 2025)	Used for remote lighting control to simulate natural daylight cycles.
LED Indicators Hua, *et al.*, 2025)	Used to provide visual feedback for system status.

Software components

This section presents the software components used for developing the proposed system as shown below (Table 2).

Table 2. Demonstrates the software components and their task

Components	Task
Wokwi (Arvindbhai and Chaubey, 2025)	Used to simulate the IoT sensors and actuators.
Node-RED (Khasawneh, *et al.,* 2025)	Used to create a real-time dashboard for monitoring and controlling the broiler house.
MQTT Protocol (Raes *et al.*, 2025)	Used for transmission of the data between sensors (in Wokwi simulator) and the dashboard (in Node-Red).

1. Wokwi online simulator

An online simulation platform is used to prototype and test the IoT system before physical deployment; it allows for real-time debugging and validation of the system's functionality.

2. Node-RED platform

A flow-based programming tool used to create a real-time dashboard for monitoring and control additionally integrates with the ESP32 to visualize temperature, humidity, water valve status, and lighting conditions.

3. MQTT protocol

MQTT (Message Queuing Telemetry Transport) is a standards-based messaging protocol, or set of rules, used for machine-to-machine communication. By using MQTT, the system achieves fast, reliable, and energy-efficient communication, improving poultry farm management, automation, and data-driven decision-making.

Table 2 demonstrate the software components and their tasks in the proposed system:

System workflow

This section presents the proposed workflow, illustrating the primary roles of each component in the system, as depicted in figure 1.

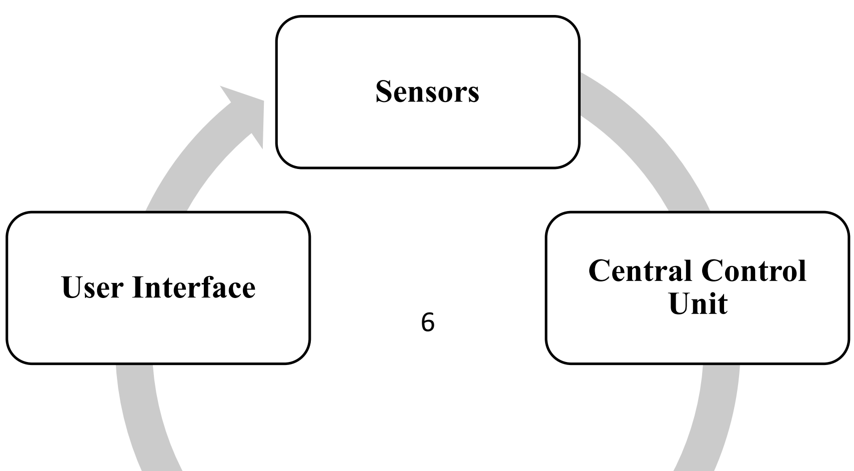

Figure 1. Demonstrates the system workflow

Sensors → Collect real-time data (from a broiler house).

Central Control Unit → Processes & Analyzes data (ESP32 Microcontroller).

Control Algorithms → Generate commands for actuators (in the Node-RED platform).

Actuators → Adjust lighting and water systems (from the Node-RED platform to IoT sensors in the broiler house).

User Interface → Sends updates to farmers (real-time dashboard and lighting, water control in the Node-RED platform).

Implementation

This section presents the step-by-step implementation of the proposed system, including hardware setup, sensor integration, data processing, and the development of the IoT dashboard for real-time monitoring and automation. The following figures demonstrate the implementation of IoT sensors in the Wokwi platform in figure 2 as well as the workflow and dashboard in the Node-Red platform in figure 3 and 4.

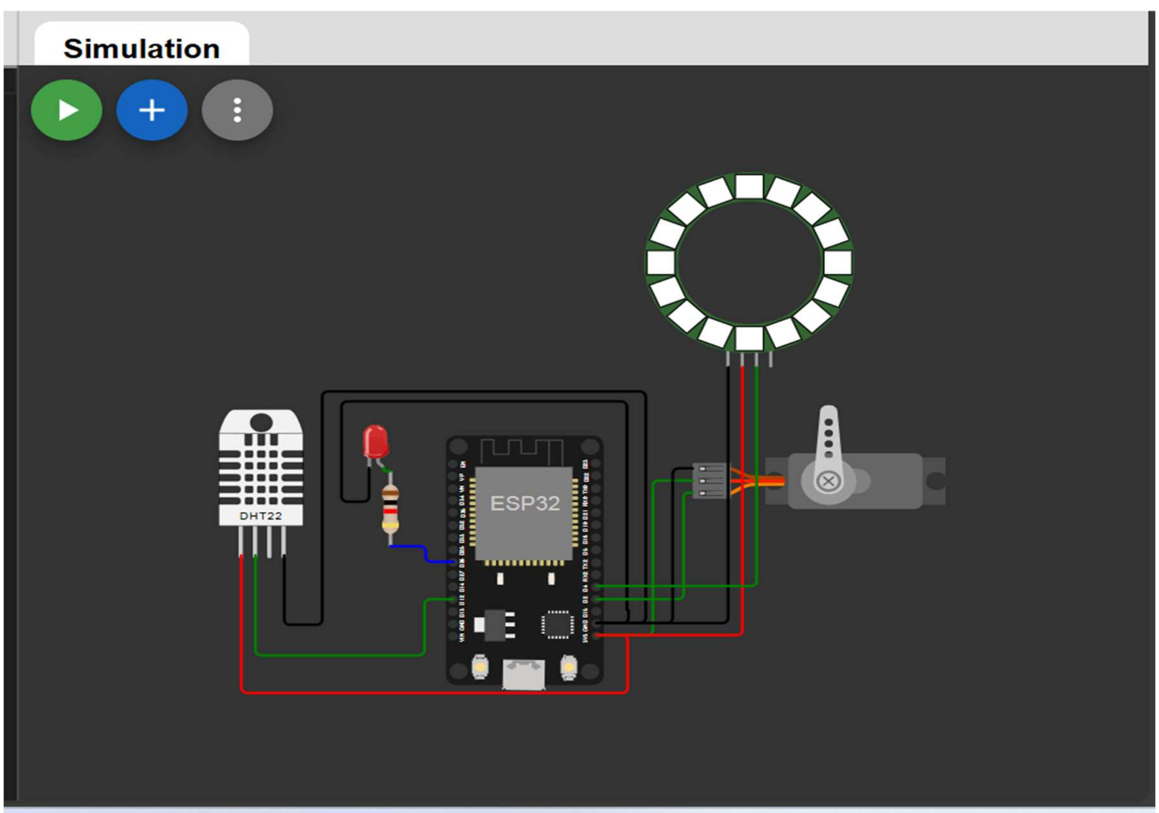

Figure 2. Demonstrates the physical connection between microcontroller and sensors, (in Wokwi simulator platform)

Table 3. Demonstrates the physical connection between microcontroller and sensors, (in Wokwi simulator platform)

Component	Pin Name	Connected To (ESP32 Pin)	Purpose / Description
ESP32 DevKit V1	TX0	Serial Monitor RX	Serial data transmission
ESP32 DevKit V1	RX0	Serial Monitor TX	Serial data reception
DHT22 Sensor	VCC	3V3	Power supply (3.3V)
DHT22 Sensor	GND	GND	Ground connection
DHT22 Sensor	SDA (Data)	GPIO 12 (D12)	Temperature and humidity data transmission
LED (Red)	Anode (A)	GPIO 26 (D26) via 1kΩ resistor	Visual status indication
LED (Red)	Cathode (C)	GND	Ground connection
Resistor	Terminal 1	LED Anode	Current limiting for LED
Resistor	Terminal 2	GPIO 26 (D26)	Protects LED from overcurrent
Servo Motor	PWM	GPIO 2 (D2)	Servo control signal
Servo Motor	V+	3V3	Power supply
Servo Motor	GND	GND	Ground connection
LED Ring (WS2812)	VCC	3V3	Power supply
LED Ring (WS2812)	GND	GND	Ground connection
LED Ring (WS2812)	DIN	GPIO 4 (D4)	Data input for LED control

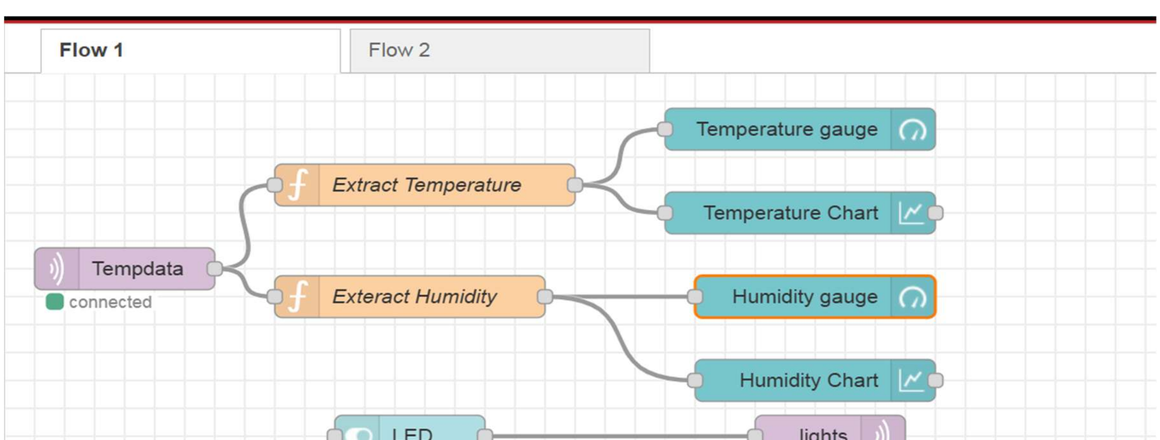

Figure 3. Demonstrates the flow and data acquisition from the microcontroller and sensors, (in Node-Red platform)

Figure 4. demonstrates the developed dashboard (in the Node-Red platform) that contains the temperature and humidity charts as well as lights and water control actuators

RESULTS AND DISCUSSION

This section illustrates the findings of the proposed system through the following figures:

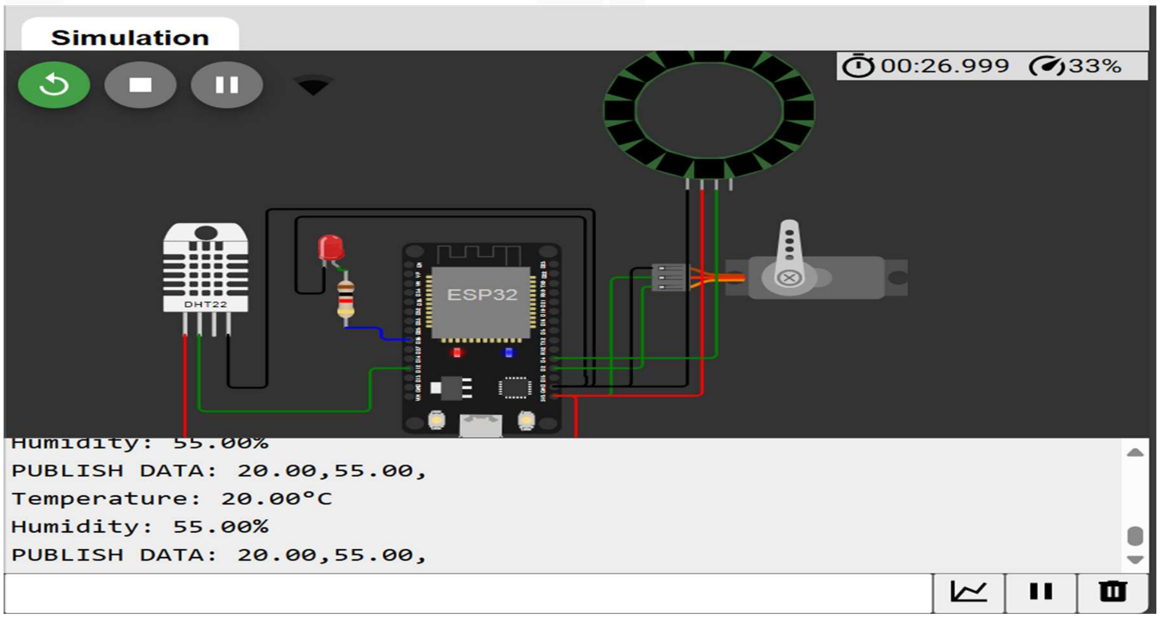

Figure 5. demonstrates the running IoT sensors in simulation that show the degree of temperature (20.00°C), humidity (55.00%), lights, (off) and servo motor degree (0)

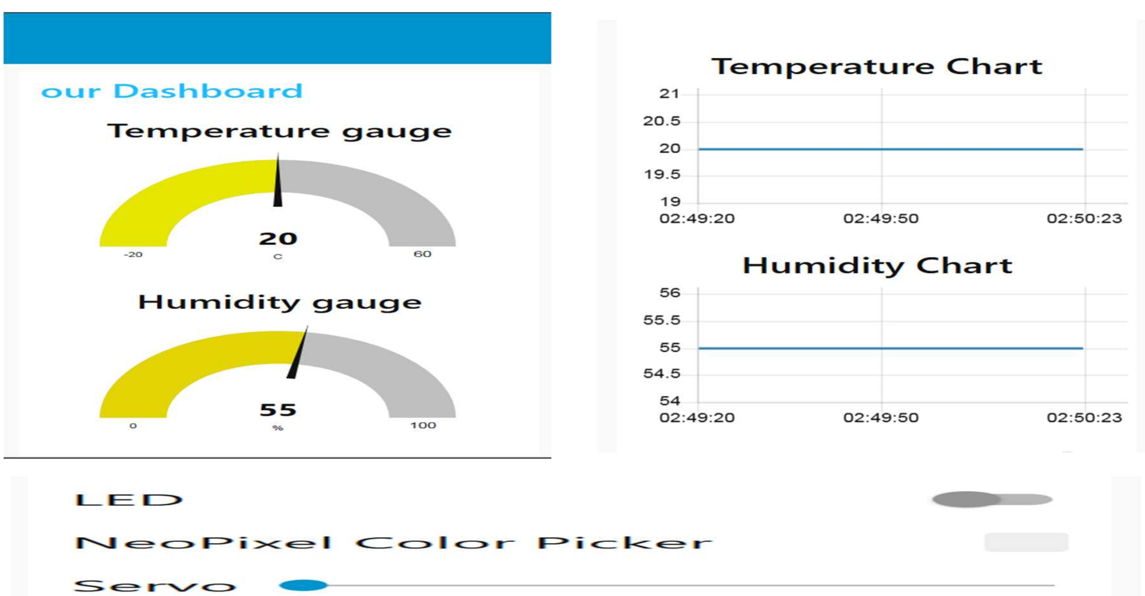

Figure 6. demonstrates the dashboard in Node-red platform that shows the degree of temperature (20.00°C), humidity (55.00%), lights, (off) and servo motor degree (0).

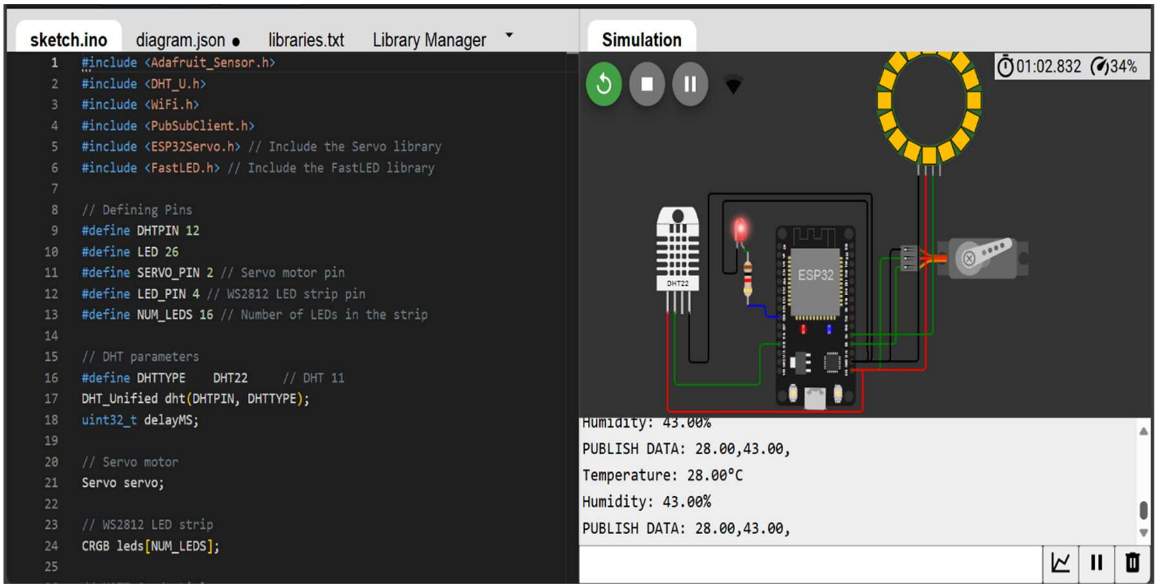

Figure 7. demonstrates the dashboard in Node-red platform that shows the degree of temperature (28.00°C), humidity (43%), lights (on, NeoPixel color to (R,G,B): 255,191,0), and servo motor degree (75)

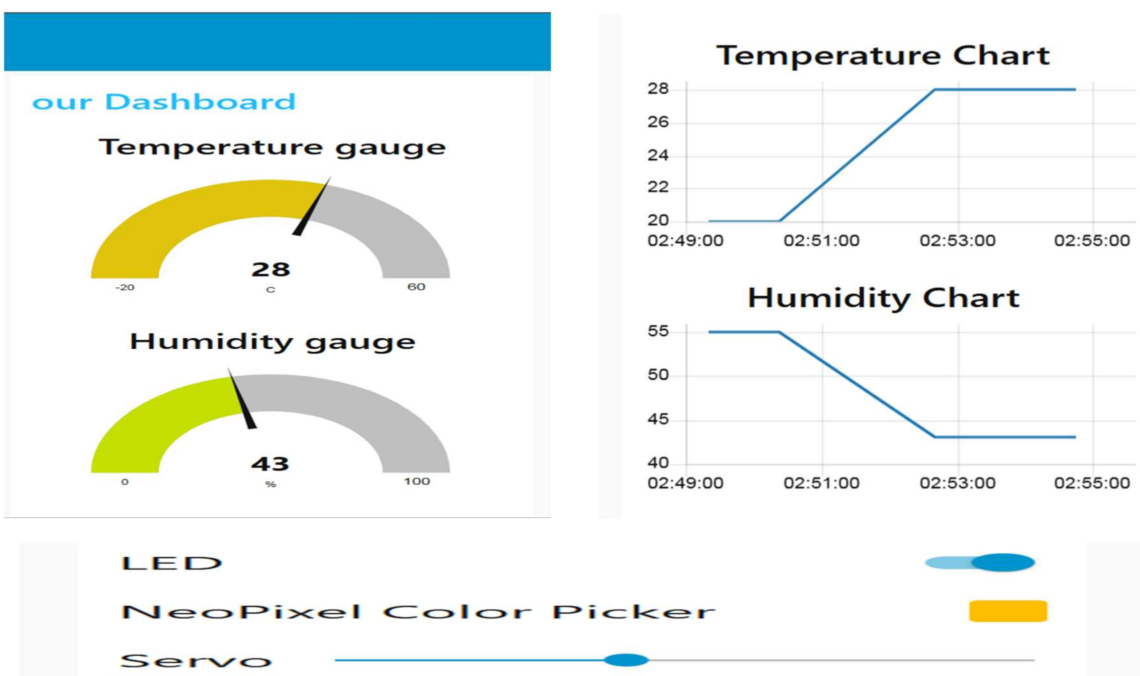

Figure 8. demonstrates the dashboard in Node-red platform that shows the degree of temperature (28.00°C), humidity (43%), lights (on, NeoPixel color to (R,G,B): 255,191,0), and servo motor degree (75)

The obtained results confirm the effectiveness of the proposed IoT-based environmental monitoring and control system in maintaining optimal poultry house conditions. The Wokwi online simulation (Figure 5) and the Node-RED dashboard (Figure 6) demonstrate normal operating conditions, where the temperature is maintained at 20.00 °C, humidity at 55.00%, the lighting system remains off, and the servo motor position is set to 0 degrees.

When abnormal environmental conditions occur specifically, an increase in temperature accompanied by a decrease in humidity (Figures 7 and 8) the system successfully detects these changes and presents them through an intuitive dashboard interface. This enables farmers to monitor real-time variations and actively control actuators, including lighting and water systems, to restore optimal conditions. Such responsive control contributes to improving broiler comfort, reducing environmental stress, and enhancing overall poultry productivity.

Compared with related works, which primarily focus on isolated monitoring or automated control functions, the proposed system offers a more integrated and interactive approach by combining real-time environmental monitoring, visualization, and user-driven actuator control. This integrated design enhances practical usability and provides a more effective solution for optimizing poultry house conditions and supporting sustainable broiler production.

CONCLUSION AND RECOMMENDATIONS

Research findings indicate that the established IoT-based environmental monitoring system generates optimal poultry house environmental conditions. Through real-time monitoring and control procedures established by the system operators can maintain stable environmental conditions which promote better broiler health and productivity results.

Wokwi online simulation as well as Node-RED dashboard enables farmers to obtain clear environmental change information that helps them make better decisions. The actuators within this system control lighting and water management to enhance farm productivity as well as poultry welfare. The automated environmental regulation system function improves efficiency while safeguarding goose growth and shows benefits for sustainable and effective farm administration.

The system could benefit from future updates that would allow AI predictive analytics to improve response time as well as enhance operational efficiency in poultry farming operations.

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الملخص

تواجه صناعة إنتاج الغذاء الحيوية المتمثلة في تربية دجاج اللحم ثلاث مشكلات رئيسية تتمثل في ضعف كفاءة استغلال الموارد، انتشار الأمراض وعدم ملاءمة ظروف النمو. ويسهم توظيف تقنيات إنترنت الأشياء في إنتاج الدواجن في تحقيق تحسينات كبيرة في الإنتاجية من خلال ضبط المعايير البيئية، والتحكم في توزيع الأعلاف وإمدادات المياه، إلى جانب أنظمة المراقبة الصحية. تقترح هذه الورقة نظام تحكم بيئي قائمًا على إنترنت الأشياء لمساكن دجاج اللحم، يعتمد على مكونات عالمية منخفضة التكلفة. يستخدم النظام المقترح مستشعر DHT22 للمراقبة المستمرة لدرجتي الحرارة والرطوبة، بما يضمن توفير الظروف المناخية المناسبة لنمو الدجاج بشكل سليم. كما يتولى النظام تشغيل إمدادات المياه باستخدام محرك مؤازر(Servo Motor) ، والتحكم في الإضاءة عبر مصابيح NeoPixel LED لضبط الإيقاع اليومي للطيور وتحسين مستوى رفاهيتها. ويعتمد النظام على المتحكم الدقيق ESP32 كوحدة معالجة رئيسية، لما يوفره من قدرات عالية على نقل البيانات بسرعة وإتاحة واجهات تحكم عن بُعد. أما على مستوى البرمجيات، فقد تم استخدام منصة Wokwi لمحاكاة نظام إنترنت الأشياء، بينما استُخدم Node-RED لبناء لوحة تحكم تفاعلية تمكّن المزارعين من مراقبة النظام وتعديل معاييره. أظهرت النتائج التجريبية للنظام قدرته على الحفاظ على المعايير البيئية المناسبة، مع تقليل متطلبات الصيانة وزيادة معدلات نمو دجاج اللحم. وتؤكد هذه الدراسة أن حلول الزراعة الذكية المعتمدة على إنترنت الأشياء تمتلك إمكانات واعدة لتحسين الإنتاجية، وخفض التكاليف التشغيلية، وتعزيز ممارسات الاستدامة في صناعة الدواجن.