ENHANCED IoT-BASED POULTRY BATTERY CAGE MANAGEMENT SYSTEM

***Okolie U. C.[1], Iloh J.P.I.[2], and Mbachu C. B[3].**

[1]Electronics Development Institute (ELDI) Awka, Anambra State, Nigeria
[2,3]Department of Electrical/Electronic Engineering, Faculty of Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Anambra State, Nigeria

*Corresponding author: okolieuc@gmail.com

ABSTRACT

This study presents an Internet of Things (IoT)-driven management system for poultry battery cages, leveraging cloud computing and computer vision technologies to improve the efficiency, productivity, and monitoring capabilities in poultry farming business. Conventional methods of poultry management are frequently characterized by high labour demands and susceptibility to human error, which can result in less-than-optimal conditions for the animals. By incorporating IoT sensors for real-time data acquisition, alongside cloud computing and computer vision techniques, this study offers an innovative approach to the monitoring and regulation of environmental factors in poultry farming operations. IoT sensors were utilized to track critical parameters, including temperature, humidity, ammonia concentrations, and lighting conditions, while computer vision algorithms based on camera input were used to assess the health conditions of the poultry. The collected data were transmitted in real time to a cloud-based platform, enabling farmers to remotely access and analyse the information via web or mobile applications. The cloud computing infrastructure facilitates data storage, processing, and predictive analytics, thereby equipping farmers with the tools necessary to make informed decisions, optimize resource allocation, and mitigate potential health risks. The findings indicated that the system was able to monitor and control the critical parameters ensuring that optimum conditions were maintained with the battery cage. The system's performance showcases the technology's potential in IoT-based poultry battery cage management systems.

Keywords: Poultry battery cage, management system, IoT sensors, cloud computing, computer vision

1.0 INTRODUCTION

This study was driven by the promise of emerging digital technologies in agriculture that offer innovative solutions to the challenges encountered by farmers, particularly in poultry farming business (Singh, 2022). The objective was to illuminate various issues faced by poultry farmers, such as disease outbreaks, while providing valuable insights for researchers aiming to tackle these challenges through advancements in digital technologies (Mishra & Sharma, 2023). Precision poultry farming leverages tools such as the Internet of Things (IoT), artificial intelligence (AI), and edge computing to improve animal health management (Boesch, 2021). A smart poultry farm is characterized by its ability to maintain optimal environmental conditions and detect diseases in chickens at an early stage (Ferehan *et al,* 2022). Resources within the smart poultry farm are utilized efficiently. The study reviewed relevant literature with respect to intelligent systems focused on the health and welfare management of poultry using technologies like IoT, AI cloud computing, and edge computing; and early disease detection, weight estimation, and feeding behaviour analysis through computer vision and vocalization analysis (Mandal, 2023). However, in the modern era, technological advancements have replaced the manual process of loading containers with grains, feeds, and water for chicken feeding (Butt *et al*, 2023). The primary issue with this approach is the constant need to supply food, stay vigilant, and be aware of the food that is left in cages. It is also unclear how much food is sufficient to be delivered. It is incredibly wasteful and unprofitable. Growers also encounter challenges in efficiently running their operations because they must periodically visit the cages to keep an eye on the chickens (Okonkwo & Ahaotu, 2019). Controlling the temperature in the cage and its surroundings is another important factor to consider when rearing chickens. The growth of chickens is significantly influenced by temperature, as they must not be exposed to extreme heat or cold. This study developed an enhanced IoT-Based Poultry Battery Cage Management System to address these identified problems. The IoT-based system was used to accomplish the tasks of autonomously feeding the chicken and maintaining optimal conditions to enhance over all well-being and ensuring profitability in poultry farming.

2.0 RELATED WORKS

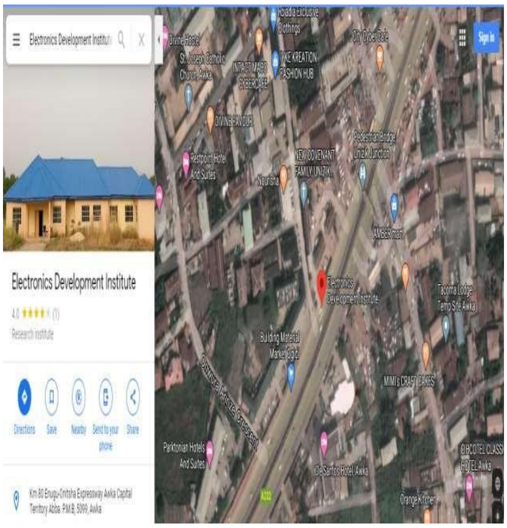
The work by Sleem *et al.* (2024), showed that in Lebanon, poultry production is one of the major components of the agricultural sector. However, it suffers from increasing energy costs necessary to cover poultry heating requirements. This affects the profits of brooding farms, namely, small-scale farms in rural areas. For this aim, two brooding cycles were chosen by the authors during the warm and cold seasons in a greenhouse and were later replicated in a conventional poultry house. The energy inputs in the green and conventional houses, respectively, were 33,995.39 and 40,656.97 MJ (1000 birds) $^{-1}$ in the warm season, and 37,058.25 and 45,770.05 MJ (1000 birds) $^{-1}$ in the cold season. Calculated energy efficiency values for the green and conventional poultry houses were, respectively, 0.58 and 0.50 in the warm season, and 0.46 and 0.41 in the cold season. The net return was negative for both systems and the benefit-to-cost ratio from broiler production was calculated to be 0.49 and 0.50 in the green and conventional houses, respectively. Due to global warming and climate change, the poultry industry is heavily impacted, especially the broiler industry, due to the sensitive immune system of broiler chickens. However, the continuous monitoring and controlling of the farm's environmental parameters can help to curtail the negative impacts of the environment on chickens' health, leading to increased meat production (Kumar *et al.*, 2023). The study recommended improved IoT-based remote poultry monitoring systems that will outperform the existing systems to boost productivity and profitability.

3.0 SYSTEM DEVELOPMENT AND IMPLEMENTATION

3.1 Testbed Description

The methodology employed in this work involved the characterization of a poultry battery cage testbed, sizing of the testbed, and data collection from the testbed to enable the accurate development of the algorithm. The testbed is located at Electronic Development Institute (ELDI), km 80 Enugu-Onitsha Expressway, Abba Junction, Awka Capital Territory. ELDI is a Research Institute under National Agency for Science and Engineering Infrastructure. Abba is one of the Communities in the present-day Njikoka Local Government Area of Anambra State, Nigeria. Abba lies on the 60 11′ N latitude, 60 55′ E longitude of the old Enugu/Onitsha trunk. The region in general has hot climate throughout the year with slight difference between summer and winter. The climate is usually characterized into two seasons – Wet and Dry. The Google map

Location and the aerial view of the testbed are presented in Figures 1 and 2 respectively.



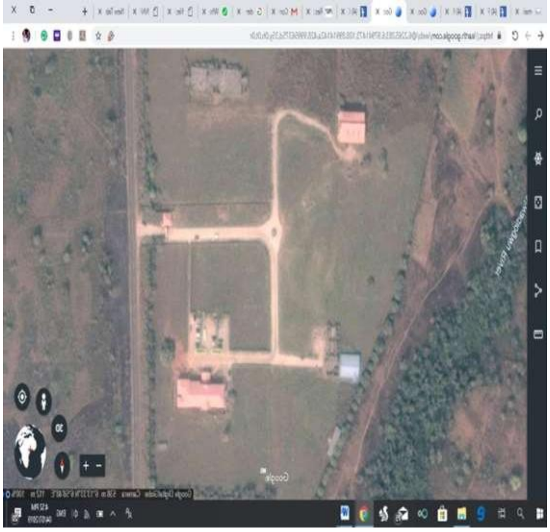


Figure 1: Google map location of test bed (ELDI). Figure 2: Aerial view of the test bed (ELDI)

3.2 Material Used

The design of the enhanced IoT-based poultry battery cage system was developed using a combination of hardware and software components. The developed system deployed the use of IoT devices and sensors for monitoring temperature, humidity, air quality, feed levels, and chicken behaviour. Microcontroller unit ESP32 and actuators were used for automated feeding, environmental control, and cage management. Machine learning models for predictive analytics, disease detection, behavioural analysis, death weight loss or gain, intruder detection and cost optimization were employed in the system. A database using machine learning was created to keep accurate information on the cost parameters incurred for maximum utilization and cost optimization. Mobile applications via web interfaces for remote monitoring, control, and decision support were also deployed. Motion sensors (PIR) were used to prevent unauthorized access into the battery cage. Integration of renewable energy sources and energy-efficient systems for sustainable operation was also implemented.

3.2.1 Hardware Components

(a) Microcontroller ESP32: The ESP32 is a budget-friendly System on Chip (SoC) microcontroller developed by Espressif Systems. As the successor to the popular ESP8266, it features either single-core or dual-core configurations of Tensilica's 32-bit Xtensa LX6 processor, and comes equipped with built-in Wi-Fi and Bluetooth capabilities. The key features of the chip include:

i. **Integrated RF Components:** Like the ESP8266, the ESP32 includes essential RF modules such as a power amplifier, low-noise receive amplifier, antenna switch, filters, and RF. This integration simplifies hardware design, minimizing the need for external components.
ii. **Processor Specs:** Single or dual-core 32-bit LX6 microprocessor, running at up to 240 MHz.
iii. **Memory**: 520 KB SRAM, 448 KB ROM, and 16 KB RTC SRAM.
iv. **Wi-Fi**: Supports 802.11 b/g/n standards with speeds reaching up to 150 Mbps.
v. **Bluetooth:** Compatible with both Classic Bluetooth v4.2 and BLE (Bluetooth Low Energy).
vi. **GPIOs:** Offers 34 programmable General-Purpose Input/Output pins.

vii. **Analog Interfaces**: Includes up to 18 channels of 12-bit SAR ADC and 2 channels of 8-bit DAC.
viii. **Serial Communication**: Features 4 SPI, 2 I2C, 2 I2S, and 3 UART interfaces.
ix. **Ethernet:** Built-in MAC for LAN communication (requires external PHY).
x. **Storage Interfaces:** One host controller for SD/SDIO/MMC and one slave controller for SDIO/SPI.
xi. **PWM Support**: Motor PWM and up to 16 channels for LED PWM control.
xii. **Security:** Supports secure boot and flash encryption for enhanced protection.

(b) DHT22 Humidity Sensor: The DHT22 is a popular digital sensor designed for precise measurement humidity. It delivers enhanced accuracy and a wider sensing range compared to its predecessor, the DHT11, making it a reliable choice for various environmental monitoring applications. He key features of the sensor include:

i. Humidity Measurement Range**:** 0% to 100% Relative Humidity (RH)
ii. Accuracy: ±0.5°C for temperature, ±2% RH for humidity
iii. Response Time**:** Delivers updated readings approximately every 2 seconds
iv. Operating Voltage: Compatible with 3.3V to 6V DC power supply.

(c) LM35 Analog Temperature Sensor: The LM35 is a widely used analog temperature sensor known for its linear output characteristics. It generates a voltage that directly corresponds to the ambient temperature, making it ideal for precise temperature monitoring in various applications. The key features of LM35 include:

i. Temperature Range: Capable of measuring temperatures from -55°C to +150°C.
ii. Linear Output: Produces an output voltage that increases by 10mV for every 1°C rise in temperature
iii. Operating Principle: Functions similarly to a diode, where the voltage across the sensor rises linearly with temperature changes

(d) DC Motor: A geared DC motor features a gear mechanism connected to its shaft. This setup enhances torque output while lowering rotational speed, making the motor ideal for a wide range of practical uses. The motor operates with its speed quantified in rotations per minute (RPM). The integrated gear system reduces the RPM and simultaneously boosts torque by leveraging gear reduction.

(e) Motion Sensors (PIR Sensors): A Passive Infrared (PIR) sensor identifies motion by detecting variations in infrared (IR) radiation which is essentially heat emitted by objects such as animals. Unlike active sensors, it does not emit any energy; it simply monitors the infrared radiation present in its environment. Its operating principle is as follows:

i. The sensor contains two IR-sensitive elements.
ii. When no movement occurs, both elements detect the same level of ambient infrared radiation.
iii. As a warm object (such as a chicken) moves through the sensor's field of view:
    - one element senses the change in IR before the other.
    - this difference generates a signal, indicating motion.
iv. When the object leaves or stops moving, the IR levels equalize again, and the sensor resets to its idle state.

3.2.2 Software components

The key software components used in developing the system includes: Proteus, MATLAB/Simulink, MIT Inventor App and the Thing Speak IoT Platform. The software architecture adopts a multi-layered structure, integrating schematic design using Proteus to simulate and test electronic circuits prior to physical implementation. Control system modeling was carried out using MATLAB/ Simulink to ensure precise system behavior. An MIT app inventor visual programming environment was used to develop the block codes that remotely control the system. The system was interfaced to the Thing Speak IoT Platform for real-time remote monitoring of the critical parameters via a graphical user interface (GUI).

Figure 3 shows the block diagram of the developed IoT-based poultry battery cage management system.

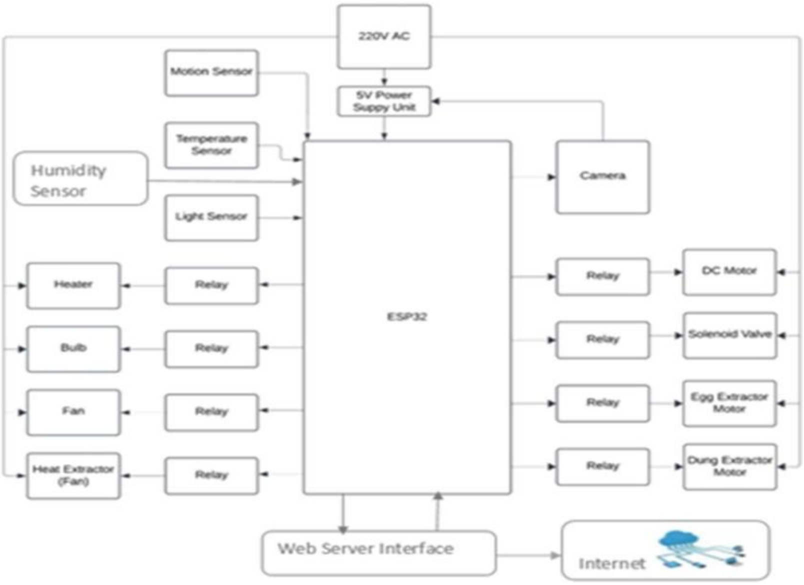


Figure 3: Block diagram of the developed IoT based poultry battery cage management system

3.2.3 Sensors and Control System Integration

The LM35 temperature sensor and DHT22 humidity sensor are interfaced with the ESP32 microcontroller via its digital serial pins GPI01 and GPI03 (TX/RX). PIR motion sensors are connected to digital pin GPI02, which also controls the on-board LED. The automatic feeder and watering system are managed through a relay module connected to digital pin GPI04.

A 10k ohm Light Dependent Resistor (LDR), used to monitor ambient light levels for illumination control, is connected to analog input pin 18 through two ADC channels. The LDR is powered by a constant 5V DC supply, and its resistance changes based on light exposure. This variation produces an output voltage that is read by pin 34 of the ESP32 and converted into a digital value ranging from 0 to 4095.To ensure efficient and timely operation, a Serial Peripheral Interface (SPI) module is integrated with the ESP32 for high-speed data transmission. It provides real-time data to coordinate feed and water delivery, minimizing system downtime. A light bulb connected to digital I/O pin 13 is toggled ON or OFF based on the LDR readings and SPI data.

Figure 4 presents the schematic diagram of the control system, detailing the interconnections among the microcontroller, sensors, actuators, and communication module. This layout serves as a guide for accurate assembly and seamless integration.

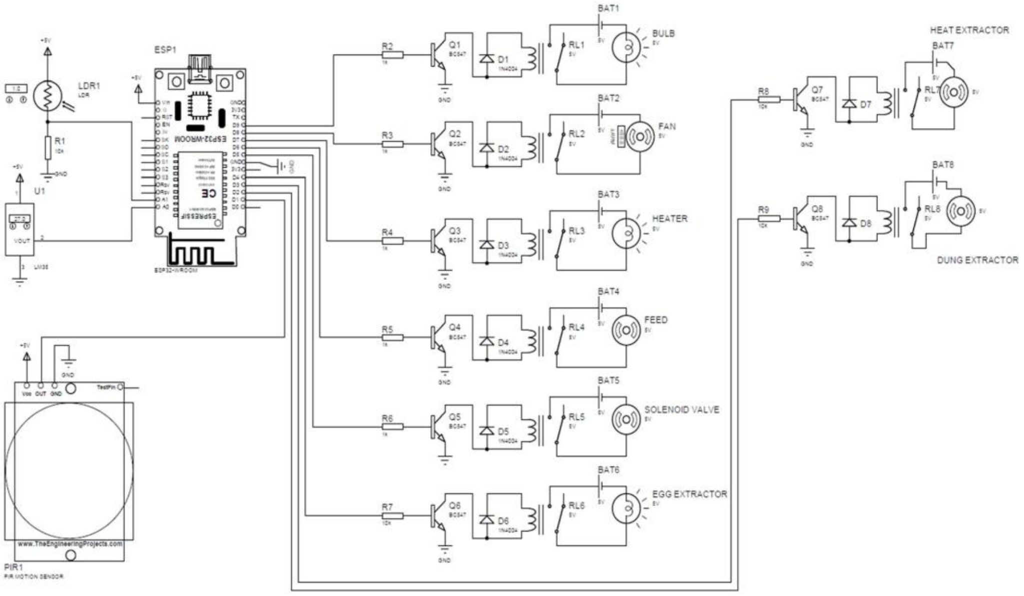


Figure 4: Schematic diagram of the control system

3.2.3 Temperature Control

Pin GPI01 of the ESP32 is connected to the LM35 sensor. A digital value between 0 and 4095 is created by converting an output voltage from the LM35 that is linearly proportional to the centigrade temperature. The LM35's output voltage is translated to temperature as follows:

$$T^0C = \frac{N \times VREF}{4095 \times 0.01} \qquad (1)$$

Where,

T^0C is the temperature in degrees Celsius (^0C)

N is the ADC Value is the number representing the digital value of the LM35 analog output, ranging from 0-4095

V_{REF} is the reference voltage for the ADC, which is 3.3V

4095 is ADC_RESOLUTION is the resolution for the 12-bit ADC of the ESP32

0.01is the Scale factor for LM35 which 0.01V per ^0C

The ESP32 reads the temperature from the LM35 and, depending on whether the temperature is above or below the defined range, either switches ON the fan or heater, which are linked to digital I/O pins 12 and 13, respectively, or turns both OFF.

4.0 RESULTS AND DISCUSSION

4.1 Results of Temperature and Humidity Monitoring and Control

Figure 5 shows the designed optimal temperature and humidity of the battery cage at 30^0 IoT system's graphical user interface, where numerical readings are displayed to help users easily assess environmental conditions. When the temperature exceeds the predefined threshold which is 29.75$^{\%}$, the system automatically activates the cooling fan or the heater. When the temperature reaches 30$^{\%}$, the blower comes up. Humidity starts at around 34% and stays flat. About 15.38 and a sharp drop occurs from 34% to 33% thus it remains steady again.

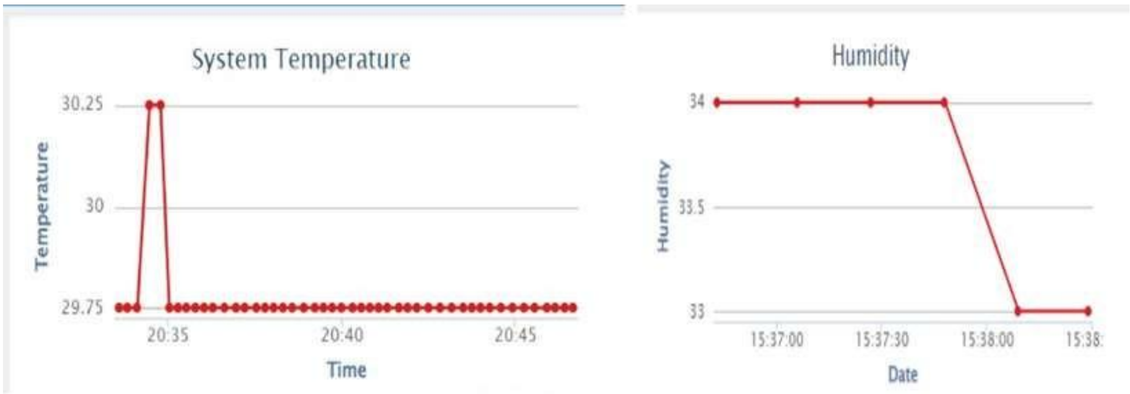


Figure 5, Temperature and Humidity control signals

4.2 Results of Water Level Monitoring and Control

Figure 6 displays the IoT-based graphical user interface for real-time monitoring of water levels at the drinker. The ESP32 Wi-Fi module sensor and connectivity tracks and report water levels in litres (L) in real-time, enabling remote monitoring and management. It indicates High reading when wet, low reading when dry. Exponential moving Average (EMA) line which is set as our threshold smoothes the data to give a stable average tend.

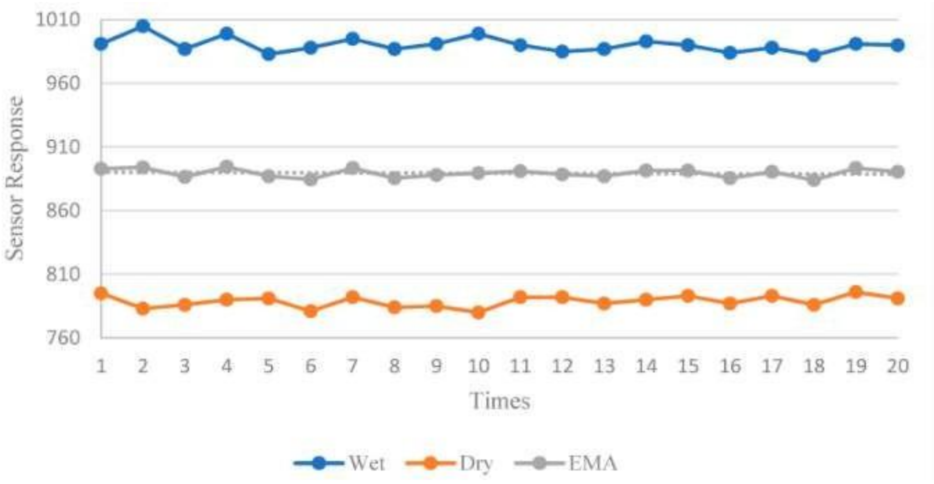


Figure 6: Water level display

4.3 Results of Incident Detection and Response

Figure 7 illustrates the system's continuous monitoring of bird behaviour to detect any unusual activity or potential security breaches. Upon identifying such incidents, the system automatically responds by notifying administrators and activating an alarm.

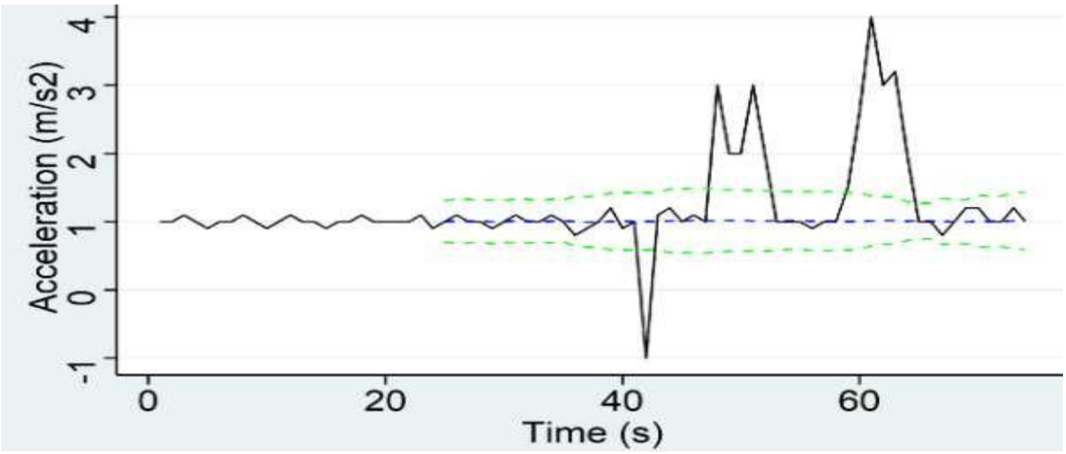


Figure 7: GUI of Incident Detection and Response (IDR)

4.4 Control Module for Feeding Tray and Faeces Removal

Figure 8 shows the control module for the feeding tray, washing and faeces management. This interface indicates when to clean the poultry house and activate the motor that controls these actions.

Figure 8: Control Module for Feeding Tray and Faeces Removal

4.5 Discussion of Results

Operational efficiency has significantly improved, resulting in reduced reliance on manual labour and lower operational costs. The integration of real-time data acquisition and analysis, as illustrated in Figures 5 (Temperature Control), 6 (Water Level Control), and 7 (Incident Detection and Management), empowers farmers to make informed decisions. This data- driven approach enables trend identification, resource optimization, and targeted interventions, ultimately maximizing poultry output and ensuring consistent farm performance.

The deployment of the developed IoT-based poultry battery cage management system led to notable improvement in farm management and productivity. Through precise monitoring and regulation of key environmental factors including temperature, humidity, theft prevention, feeding, water level control, egg collection, farm sanitation, and early detection of sick birds the system creates optimal conditions for poultry health and growth. This, in turn, boosts production rates and enhances the overall quality of poultry products.

5.0 CONCLUSION

The implementation of an affordable smart device on agricultural premises can yield significant advantages for economically disadvantaged farmers while simultaneously enhancing farm productivity. Such a device contributes to creating a secure habitat for avian species, ensuring that adequate food and water supplies are maintained, which is crucial in mitigating the risk of infections detrimental to bird health. Furthermore, it plays a vital role in curbing the transmission of diseases. The technology facilitates the operation of poultry farms with minimal labour requirements and helps in conserving electricity. The proposed approach effectively addresses the various factors influencing avian health and offers protection against theft and fire incidents. It fosters an environment conducive to the well-being of birds and enhances management and monitoring practices. This, in turn, supports the health and growth of the avian population. The initiative aligns with several Sustainable Development Goals, including the eradication of poverty, promotion of good health and well-being, provision of clean water and sanitation, creation of decent work and economic growth, and advancement of climate action.

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