IoT-Enabled Smart Light Management System for Enhancing Layer Quail Farming Efficiency

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Abstract— In Thailand, small-scale farmers are becoming interested in quail farming because it is relatively inexpensive to start, easy to operate, requires minimal space, and produces many eggs quickly. However, if the illumination is not correct, it may significantly reduce egg production. Additionally, controlling temperature and humidity in the area is crucial for maximizing productivity and maintaining the birds' health. This article discusses the development of a smart light management system that integrates with the Internet of Things (IoT) to enhance the efficiency of laying quail farming. A smartphone dashboard lets you monitor and operate the system from anywhere. The experiment utilised LED lights of various colours and photoperiods in different containers. We maintained the temperature at 30°C and the humidity at 65%. When necessary, a sprinkler system was used to lower the temperature. When there was excessive humidity, ventilation fans were used to regulate the level. The results showed that the LED light spectrum had a significant influence on how eggs were made. A 14:2 hour red-to-green light cycle gave the best results. The results indicate that utilizing LED lights with specific spectral qualities is an effective method for enhancing egg production, improving bird health, and increasing egg yield.

Keywords—laying quail farming, Internet of Things (IoT), smart poultry farm, colored lighting, control system.

I. Introduction

Quails (*Coturnix* spp.), commonly referred to in Thailand as “nok krata” or “nok khum,” are small, ground-dwelling birds of the order *Galliformes*, which also includes chickens, pheasants, and turkeys. These birds are distributed across both the Old World (Europe, Asia, and Africa) and the New World (North and South America and Australia). Quails are generally characterized by their small size, compact body structure, muted plumage with spotted markings, and short wings and tails, which limit their flight to short distances [1].

In Thailand, the Japanese quail (*Coturnix japonica*) is the only species reared for commercial purposes. Although originally domesticated for its vocalizations, it is now primarily bred for meat and egg production [2]. The increasing demand for high-protein food sources, coupled with the need for supplemental income among rural households, has positioned quail farming as a viable strategy for small-scale agricultural development. Reference [3] states that Sakon disseminated knowledge on quail farming to interested individuals and communities, enhancing their understanding and practices and promoting quail rearing as a sustainable livelihood option. Currently, quail meat is priced at 100-125 baht per kilogram, quail eggs at 80-100 baht per 100 eggs, and quail droppings at 50 baht per bag. However, environmental factors, particularly temperature, humidity, and light, have become increasingly unpredictable due to climate variability, posing significant challenges to quail reproductive performance, especially egg production [4]-[5]. Among these factors, light plays a critical role in regulating reproductive physiology in avian species, including poultry. As such, the management of lighting conditions has become a key focus for enhancing reproductive efficiency and overall productivity in poultry systems [6].

To address these challenges, the development of cost-effective, automated systems capable of controlling environmental parameters such as lighting, humidity, and temperature represents a promising solution. The integration of Internet of Things (IoT) technologies into quail farming systems offers dual benefits: it enables farmers to gain experience in implementing intelligent control systems on their farms while also enhancing quail egg production and income generation. Such innovations contribute to the broader objective of promoting sustainable rural development through increased technological adoption in Thailand’s agricultural sector [7].

The objective of this research is to design and implement an Internet of Things (IoT)-based smart lighting management system to enhance efficiency in layer quail farming. The proposed system aims to stabilize egg production, minimize reliance on manual labor, and improve overall operational performance within the farming environment.

II. Literature Review

Smart poultry farming integrates information and communication technologies such as the Internet of Things (IoT) and cloud computing to enhance the precision, efficiency, and sustainability of poultry production. The increasing deployment of internet-connected sensors and devices enables real-time monitoring of critical parameters such as ambient temperature, humidity, air quality, feed and water intake, and animal behavior. IoT-based systems play a vital role in poultry farm management, including automated environmental control, health monitoring, and unmanned feeding or cleaning systems. Wireless communication technologies such as Wi-Fi, LoRaWAN, cellular networks (4G, 5G), ZigBee, and Bluetooth are widely applied to support reliable data transmission in poultry environments. These innovations help improve productivity, animal welfare, biosecurity, and reduce labor, contributing to greater food security and self-reliance, especially in low- and middle-income countries. [8]-[12].

Light exposure has long been recognized as a major factor influencing reproductive behavior and physiological development in birds. In poultry, light regulates critical reproductive functions, including the onset of sexual maturity and the modulation of egg-laying cycles. The avian reproductive system is highly responsive to photoperiod (duration), light intensity, and spectral composition. In natural environments, many bird species initiate breeding in response to seasonal light changes, underscoring the need for artificial lighting control in commercial poultry farming systems [13].

Optimizing lighting conditions through adjustments in intensity, duration, and color has been shown to significantly enhance reproductive efficiency and egg production across various poultry species. Numerous studies have confirmed that red and warm-white LED lighting improves laying performance, while extended photoperiods of 14–16 hours per day promote more consistent ovulation [14]–[16]. Consequently, the integration of automated lighting technologies has gained increasing attention in intensive poultry farming systems. Several studies have demonstrated the effectiveness of IoT-based lighting control systems in layer and broiler production. For example, Habibuddin et al. [17] developed a light intensity monitoring system for broiler chicken coops using an ESP32 microcontroller and BH1750 sensors to measure both indoor and outdoor light levels. The system utilizes the Arduino IoT Cloud platform to allow remote access via smartphone, enabling timely adjustments of curtains and lighting to optimize environmental conditions and improve broiler health and productivity. Similarly, Goswami [18] proposed an automatic lighting and heating system for poultry farms based on Arduino. This system autonomously regulates ambient temperature, and its status can be monitored through a Bluetooth-connected Android mobile application, eliminating the need for constant human supervision. Furthermore, Karun [19] introduced an IoT-based smart poultry management system that automates essential tasks such as feed dispensing, water supply through nipple drinkers, environmental control using fans and heaters, lighting regulation, and real-time monitoring via cloud-based platforms. These innovations contribute to increased operational efficiency and improved animal welfare in modern poultry production systems.

However, climate variability and unpredictable environmental conditions, particularly fluctuation in light and temperature, continue to pose significant challenges to smallholder poultry productivity. In this context, the development of cost-effective, IoT-based solutions for managing lighting and environmental parameters offers a promising approach to improving reproductive performance and economic sustainability in quail farming. By enabling precise control of lighting regimes, such systems can promote consistent egg production while simultaneously reducing labor demands and energy consumption.

III. Proposed System

This section outlines the design of the quail farming system and the placement of control equipment necessary for implementing an IoT-based light management solution. The proposed system focuses on achieving optimal environmental conditions, particularly lighting, to support enhanced egg production in layer quail farming.

A. Housing Layout and Control Equipment Placement

The housing layout was developed with consideration for airflow, accessibility, and even light distribution. The quail cages are arranged in parallel rows with adequate spacing to facilitate ventilation and maintenance. Overhead lighting is installed along the central axis of the facility to ensure uniform light exposure across all houses.

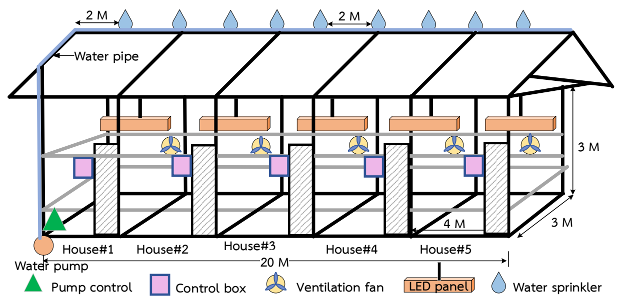

Fig. 1. Farm layout and control equipment placement.

The experimental setup consisted of five houses, each measuring 3 × 4 × 3 meters. Each pen was equipped with an automated lighting system programmed to deliver the respective light treatments during the period from 16:00 to 08:00 the following day (a total of 16 hours). Each large pen was divided into four sub-pens, with each sub-pen measuring 1.5 × 1.5 × 3 meters. Each sub-pen housed 40 quails aged 35 days, yielding a total of 800 birds (with a floor space allowance of approximately 562.50 cm² per bird). As per standard guidelines for layer quail housing, a space allocation of 180–200 cm² per bird is recommended. Fig. 2 illustrates a diagram of the housing arrangement provided in the accompanying figure.

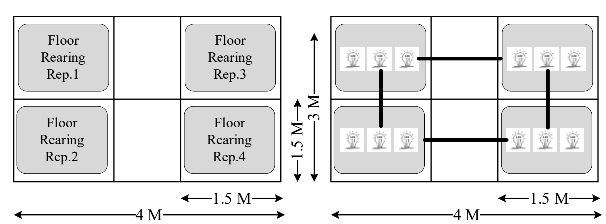

Fig. 2. Layout of each house used to raise quails and an LED panel

B. Control Devices and Installations

The control system for enhancing the efficiency of layer quail farming using IoT technology is designed to manage temperature, humidity, and lighting conditions within each poultry house. As shown in Figure 3, the control box houses key components, including a circuit breaker, magnetic contactor, ESP32 microcontroller, automatic switch, and terminal box. Temperature and humidity sensors are installed at the LED panel, while the router is mounted externally on top of the control box. Figure 4 shows the installation of the water pump, pump controller, LED panel, and ventilation fan for decreasing the humidity in the house. As illustrated in Figure 5, the control box is installed adjacent to the entrance of each house, and a rooftop sprinkler system is installed to support cooling operations.

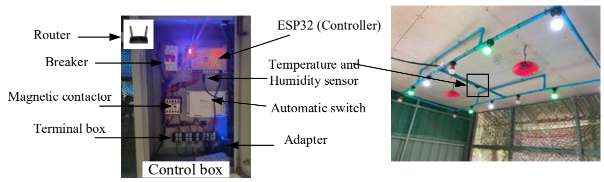

Fig. 3. Control devices and installation IoT system in the control box.

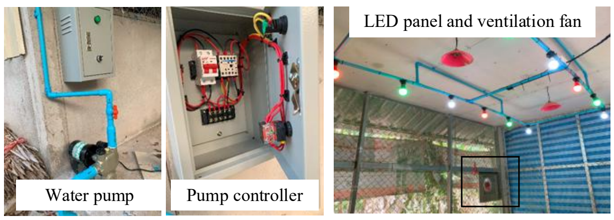

Fig. 4. Installation of water pump, pump controller, LED panel, and ventilation fan.

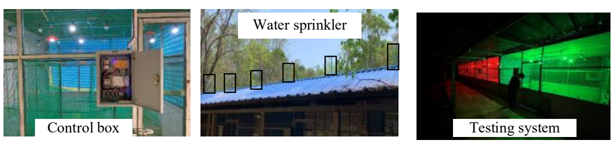

Fig. 5. Completed IoT-based system for light management in layer quail farming.

C. Setting the Experimental Conditions

The housing environment was designed to maintain optimal lighting, temperature, and humidity conditions suitable for layer quail production. Figure 6 illustrates the flow chart of the proposed system. The light management protocol included five experimental treatments, each assigned to a separate poultry house, as follows:

- Treatment 1: Exposure to 16 hours of red light.
- Treatment 2: Exposure to a combination of red and green light in a 14:2 hour ratio.
- Treatment 3: Exposure to a combination of red and green light in a 12:4 hour ratio.
- Treatment 4: Exposure to 16 hours of green light.
- Treatment 5: Exposure to 16 hours of white light.

Following system initialization, the IoT-based platform continuously monitors ambient temperature and relative humidity within the farm environment. Sensor nodes, interfaced with an ESP32 microcontroller, acquire environmental data at randomized 30-minute intervals. When the temperature exceeds the predefined threshold of 30 °C, the control algorithm activates the water pump module, initiating a 5-minute irrigation cycle through sprinkler heads mounted on the farm ceiling. The water pump is controlled via a magnetic contactor to operate these sprinklers, ensuring precise timing and energy efficiency. Similarly, when the relative humidity exceeds 65%, the system engages the ventilation of each poultry house by activating a fan module for 5 minutes to improve airflow and reduce excess humidity. This process is regulated via relay control and embedded logic within the firmware. After each intervention, the system enters a 30-minute standby mode before resuming environmental monitoring. This control strategy ensures efficient operation, prevents excessive cycling of hardware components, and maintains optimal environmental conditions for quail health and egg production.

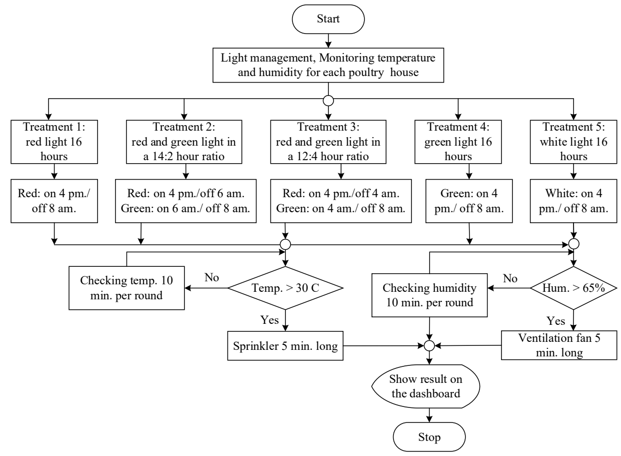

Fig. 6. Flow chart of the proposed System.

D. Dashboard

The dashboard preview below in Fig. 7 shows the real-time farm conditions of each poultry house, such as setting the time to turn on and off the lights, temperature, and humidity data. Along with that, we can record the chickens' health conditions to track our healthy chicken count. Those are alive, so that we can separate the dead or affected chickens. Besides that, we have an alarm system that will trigger if anything is mismatched or in trouble, so that we can take action accordingly.

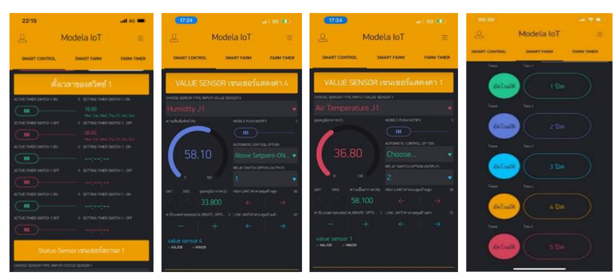

Fig. 7. Dashboard and setting parameters.

IV. Results and Discussions

This section presents the findings of an experimental study investigating the effects of LED light color and photoperiod on the productivity and egg quality of laying Japanese quails. Fig. 8 illustrates the quail egg production process in conjunction with systematic research data recording. The experimental setup includes designated enclosures for layer quails, optimized for environmental control, and equipped with IoT-based sensors for real-time monitoring. Key performance indicators such as hen-day egg production, bird viability, yolk color, and Haugh unit were analyzed across five different light treatment groups. The results are interpreted in the context of physiological responses and existing literature. After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As

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A. *Hen-Day Production (%)*

Hen-day production, reflecting the laying rate of quails, was markedly influenced by LED light treatments (P = 0.0004). The maximum output occurred under the Red: Green 14:2 hour lighting regimen (72.79%), followed by pure red light at 16 hours (64.90%). The minimal output occurred under white light (58.99%). This outcome indicates that the combination of red and green light for 14 and 2 hours, respectively, may best enhance the reproductive system in quails, likely because of red light on the hypothalamic-pituitary-gonadal axis [20]. Red light is recognized for its superior tissue penetration and ability to affect gonadotropin secretion, increasing egg production [21].

B. *Viability (%)*

No statistically significant variations in viability were seen across the treatments (P = 0.296), with all groups exhibiting reasonable survival rates (between 93.75% and 96.09%). This suggests that the hue of LED light did not negatively impact the health or survival of the birds. Olanrewaju [22] reports analogous findings indicating that although light hue may influence productivity, its effect on mortality is minimal when environmental and dietary variables are regulated.

C. *Egg Yolk Colour*

The egg yolk colour did not vary significantly among treatments (P = 0.517), with values spanning 11.611 to 11.825. This indicates that the colour of LED light has minimal to no effect on yolk coloration under the present experimental settings. The colour of yolk is predominantly determined by nutrition, particularly the consumption of carotenoids, rather than by illumination [23]. Consequently, the homogeneous diet probably led to consistent yolk coloring across treatments.

D. *Haugh Unit*

Among the illumination treatments, no significant differences were seen in the Haugh unit (P = 0.155), an indicator of egg interior quality. Values remained continuously elevated (82.91 to 83.53), signifying superior albumen quality across all groups. The absence of variation corresponds with research indicating that the interior quality of eggs is more influenced by the age and diet of hens than by lighting conditions [24]. The stable Haugh unit values indicate that light colour does not influence albumen height or quality under these conditions.

Fig. 8. Quail egg production and research data recording process.

TABLE I. IMPACT OF LED LIGHT COLOUR (RED, GREEN, AND WHITE) ON PRODUCTIVE PERFORMANCE AND EGG QUALITY OF LAYING JAPANESE QUAILS DURING THE 4-20 WEEK PERIOD.

Parameters	LED light colour (Hour)					*P*-Value
	Red (SD) (16 hr)	Red:Green (SD) (14:2 hr)	Red:Green (SD) (12:4 hr)	Green (SD) (16 hr)	White (SD) (16 hr)	
Productive performance						
Hen day Production (%)	64.901±2.744^{B}	72.792±2.406^{A}	60.746±5.281^{BC}	59.224±3.748^{BC}	58.998±3.362^{C}	0.0004**
Viability (%)	93.797±0.095^{A}	93.750±0.000^{A}	96.094±1.563^{A}	96.094±2.992^{A}	94.531±2.992^{A}	0.296^{NS}
Egg Quality						
Egg yolk colour	11.611±0.30^{A}	11.825±0.164^{A}	11.634±0.110^{A}	11.630±0.175^{A}	11.666±0.142^{A}	0.517^{NS}
Haugh unit	83.536±0.116^{A}	83.162±0.072^{A}	83.187±0.314^{A}	83.039±0.488^{A}	82.912±0.451^{A}	0.155^{NS}

^{NS}: Non-Significant (P>0.05)

$^{A\text{-}C}$ Values within a row with different superscripts differ significantly at the following levels: **, Highly Significant (P<0.01)

V. CONCLUSION

In conclusion, only the hen-day production attribute was significantly affected by the color of the LED light, with the Red: Green (14:2 hr) combination proving to be the most effective. Other characteristics, such as bird viability, yolk pigmentation, and Haugh unit, were not significantly influenced. These findings support the use of specific light spectra as an effective method to enhance egg production while maintaining avian health and egg quality. Furthermore, the implementation of the IoT-enabled smart light management system demonstrated its potential to improve the overall efficiency of layer quail farming by enabling precise environmental control and real-time monitoring, making it a practical solution for modern smart agriculture applications.

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