

MONITORING ENVIRONMENTAL PARAMETERS IN POULTRY HOUSES USING IOT

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ABSTRACT

High gas levels in poultry houses, namely carbon dioxide (CO₂) and ammonia (NH₃), can cause stress, impair respiration in the birds, reduce egg production, and increase their disease susceptibility. Therefore, this study presents an IoT-based monitoring system built on an Arduino ESP32 microcontroller and integrated with DHT22, MQ-135, and MQ-137 sensors for measuring key environmental parameters in poultry houses. The system monitors temperature, humidity, NH₃, and CO₂ in both closed and open laying hen housing systems. Environmental data were stored in the cloud to enable remote, real-time monitoring and subsequent analysis. The results showed that closed housing systems are more suitable for regulating temperature and humidity while keeping gas levels within permissible limits inside poultry farms, thus leading to improved egg production. The proposed IoT-based monitoring system offers a practical tool for improving poultry management and reducing losses associated with poor air quality, ultimately helping farmers enhance production efficiency.

Introduction

Poultry farming plays a vital role in food and nutrition security and in supporting rural livelihoods, particularly in developing countries. It provides an affordable and reliable source of high-quality protein in the form of eggs and meat, while also contributing to income generation for smallholder farmers, promoting gender-inclusive employment, and supporting

broader socio-economic development (Attia et al., 2022; Honyal et al., 2025). Thus, the sector plays a critical role in driving economic development, particularly through substantial growth in egg and meat production, which supports income generation and contributes to the national economy (Barnwal et al., 2021). The efficiency and sustainability of poultry production, however, are strongly dependent on the environmental conditions maintained within poultry houses. Microclimatic factors such as temperature, relative humidity, and concentrations of harmful gases, including ammonia (NH_3) and carbon dioxide (CO_2), have a direct and measurable influence on bird health, growth performance, feed conversion efficiency, and overall productivity (Abbas & Comini, 2025; Dawkins et al., 2004; Lin et al., 2006).

Optimal thermal conditions should be aimed at maintaining metabolic balance without causing heat or cold stress to the poultry. The most critical factors affecting bird performance, feeding efficiency, and good health are ambient temperature and humidity. Proper temperature helps to stabilize body functions, thus reducing heat stress. Relative humidity should be carefully controlled to reduce litter moisture and prevent respiratory diseases (Lin et al., 2006). Appropriate adjustment of these parameters ensures suitable environmental conditions that support animal welfare and optimal production performance. NH_3 , as a byproduct of uric acid breakdown by bacteria in the poultry droppings, should not exceed 25 ppm because high concentrations are detrimental, causing respiratory stress, immunosuppression, and damage to the cornea in the eyes of the birds; moreover, it reduces eggshell formation by the birds (Al Homidan et al., 2003; Miles et al., 2004). One of the main by-products that must be monitored is CO_2 , since high concentrations (>2500 ppm) are correlated with reduced availability of oxygen and increased bird mortality (Lashari et al., 2023). Temperature has a significant effect on NH_3 and CO_2 concentrations in the air of laying hen houses. The temperature, relative humidity, and NH_3 levels widely affect the health and productivity of laying hens (Kilic & Yaslioglu, 2014). Optimum recommended conditions are 18°C for temperature, 50-70% for relative humidity, low concentration of NH_3 , since high levels are very detrimental to the required welfare and performance of the birds (Prodanov et al., 2016). Feed consumption and egg quality (measured as shell thickness and egg mass) were lower at higher NH_3 concentrations (Li et al., 2020). Results of the investigation conducted by (Kim et al., 2024) showed that under heat stress in laying hens expressed by the temperature humidity index, levels are significantly low in feed intake, egg production, and quality of eggs, together with some imbalances of blood electrolytes. These findings highlight the need for effective environmental management to ensure poultry health and productivity under heat stress conditions.

Maintaining good environmental conditions in poultry houses can be somewhat costly, but the losses resulting from poor air quality, including reduced bird health and productivity, have far greater economic consequences (Prodanov et al., 2016). Smart sensing technologies, Internet of Things (IoT) monitoring systems in a poultry house, are a cost-effective, real-time practice, solving today's environmental issues by making systems that enable steady data collection and timely interventions for maintaining ideal housing conditions, besides reducing stress on the part of production outcomes (Orakwue et al., 2022); Rawdhan et al. (2026). (Binisha et al., 2024) designed an IoT system for monitoring temperature, humidity, NH_3 , and CO_2 levels in poultry farming. (Ahmed et al., 2024) proposed a smart poultry monitoring system that adopts IoT sensors to detect and monitor chicken behavior in poultry farms. (Alvi & Mondal, 2023) proposed a low-cost IoT-based sensing device for monitoring of CO_2 , NH_3 ,

temperature, and humidity in poultry facilities. It is meant for low-resource settings, for remote real-time monitoring as well as automatic control of gas levels, offering a pragmatic solution for the environmental control of developing countries. Continuous assessment and control of temperature, humidity, NH_3 , and CO_2 levels are essential to ensure bird welfare and to reduce productivity losses in commercial poultry farms. This study aims to design and implement an IoT-based monitoring system based on Arduino ESP32 to monitor environmental parameters, such as temperature, humidity, NH_3 , and CO_2 levels, in closed and open poultry houses.

Materials and methods

Experimental design

The experiment was conducted at the Poultry Research Directorate, Ministry of Agriculture, located in Abu Ghraib district, Baghdad city, Iraq, during January 2025. The study aimed to evaluate the indoor environmental parameters and productivity in two poultry housing systems (Figure 1), first a closed system and the other is open system, using Arduino-based sensor technology. The open system utilizes natural ventilation, whereas the closed system features well-insulated conditions with mechanical environmental control. Each system housed 30 laying hens; the dimensions were 5 x 1.5 meters. The environmental sensors were placed at a height level of 70 cm above the floor, which is close to the normal breathing level of the birds, in a way that ensures that the measured air quality represents what the birds experience. Hence, this height helped protect the sensors from damage that is caused by the birds, dust, litter movement, and routine activities inside the poultry house. In this experiment, Iraqi local brown laying hens were used at 43 weeks of age, with a body weight ranging from 1850 to 1950 g. At this age, the birds were in their active laying period. All hens were maintained under identical management conditions, including feeding and housing, throughout the 25-day experimental period.



Figure 1. Photographs of the open and closed poultry housing systems.

Environmental parameters monitoring system

In this study, an IoT system was designed to monitor the temperature, humidity, NH_3 , and CO_2 levels in both open and closed poultry housing systems. To monitor environmental parameters with accuracy, cost-effectiveness, and affordability, a custom-built electronic data acquisition system was developed using the Arduino ESP32 microcontroller unit. The ESP32 unit was selected for its low cost, wide availability, and ease of use, making it accessible for a broad range of users and applications. The IoT system was designed to continuously read data from gas and climate sensors, then transmit the readings to the user via Google Cloud, enabling real-time monitoring and informed decision-making. Every sensor provided individual readings that were calibrated according to experimental requirements. Users also had the option to recalibrate sensors to suit specific conditions or accuracy needs. The layout of the IoT data monitoring system is illustrated in Figure 2.

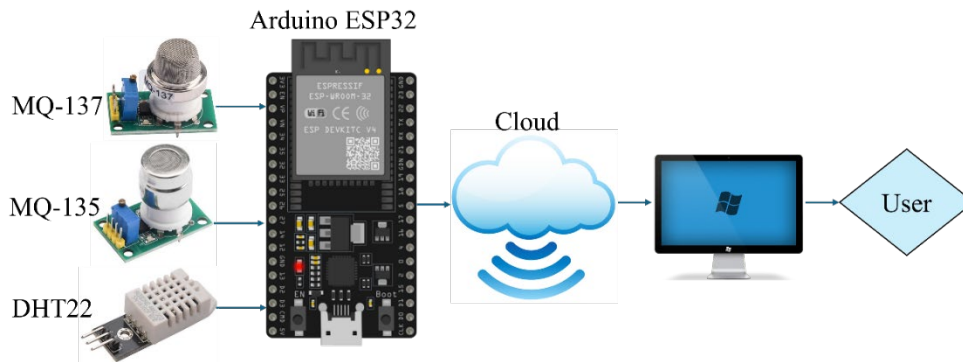


Figure 2. Schematic diagram of an IoT system for monitoring environmental parameters.

The IoT hardware components are as follows:

(a) Arduino ESP32: The ESP32 board, designed by Expressive Systems, is characterized by a dual-core processor (up to 240 MHz) and 520 KB of RAM, supporting diverse digital communication protocols such as I²C, SPI, UART, PWM, ADC, and DAC. Its architecture (Tensilica Xtensa LX6) is well-suited for IoT applications, offering low power consumption and various connectivity options. The ESP32 unit served as the core processing unit for the entire system.

(b) DHT22 temperature and humidity sensor: The DHT22 sensor was used to monitor the ambient temperature (°C) and relative humidity (%) within each poultry house. It provides reliable readings with adequate/ enough accuracy for indoor environmental applications. DHT22 uses a capacitive humidity sensor along with a thermistor for temperature measurement and communicates via a single digital signal. It works at a voltage of 3–5V, making it compatible with the ESP32 unit. The DHT22 sensor was selected due to its suitability for real-time indoor environmental monitoring.

(c) MQ-135 gas sensor: The MQ-135 sensor is designed for air quality monitoring, with high sensitivity to multiple gases, including NH_3 , CO_2 , benzene, alcohol, and smoke. It operates based on changes in the conductivity of tin dioxide (SnO_2) in the presence of target gases. In this study, the MQ-135 sensor was used to detect CO_2 levels.

(d) MQ-137 gas sensor: This sensor is optimized for NH_3 detection and utilizes metal-oxide semiconductor technology. Its sensitivity response to NH_3 ranges from 10–300 ppm, with the added ability to detect minor levels of methane and hydrogen. The change in conductivity upon gas exposure is converted to an electrical signal, which is in turn processed by the ESP32 unit.

To ensure uniformity in data collection, all sensors were installed centrally inside each poultry house at a height of 70 cm above ground level, as shown in Figure 3. This placement of sensors reflected the actual environmental exposure experienced by the hens. All gas sensors are calibrated using a portable multi-gas analysis instrument (model S360, China). The DHT22 sensor for temperature and humidity is calibrated using a digital thermometer hygrometer (model: HTC-1, China).

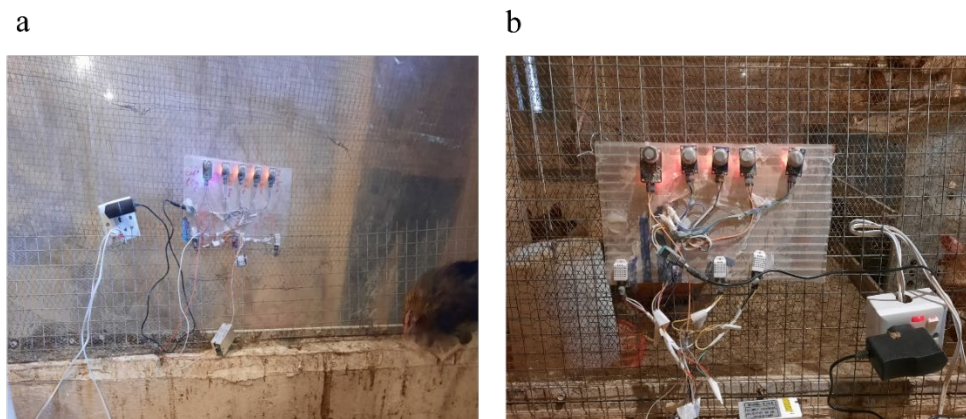


Figure 3. Photograph of environmental sensor installation locations: (a) closed and (b) open poultry housing systems

Measurements and statistical analysis

In this study, the temperature, humidity, NH_3 , and CO_2 levels were measured and quantified in both open and closed poultry housing systems every 5 minutes over 25 days of the experiment. Also, egg production was recorded daily for each housing system. Productivity was expressed as the average number of eggs per day for each system, and values were gathered for analysis over the period of 25 days.

Descriptive statistics, including mean, median, standard deviation, minimum, and maximum recorded values, were computed for all measured variables. To assess and compare the significance of differences between the two housing systems, independent samples t-tests were performed and used for each parameter using Origin Pro 2024b. Statistical significance was determined at the $p < 0.05$ level. Additionally, correlation analysis was conducted to

evaluate the relationship between environmental parameters, using Pearson's correlation coefficient.

Results and discussion

Hourly and daily monitoring of environmental parameters in closed and open poultry housing systems

The hourly variations of environmental parameters – temperature, relative humidity, NH_3 , and CO_2 – recorded in the open and closed poultry housing systems are presented in Figure 4. Temperature profiles (Figure 4a) indicate that the open housing system exhibited greater variability throughout the day – reflecting its dependence on external weather conditions. In contrast, the closed housing system maintained more stable thermal conditions due to insulation and mechanical control.

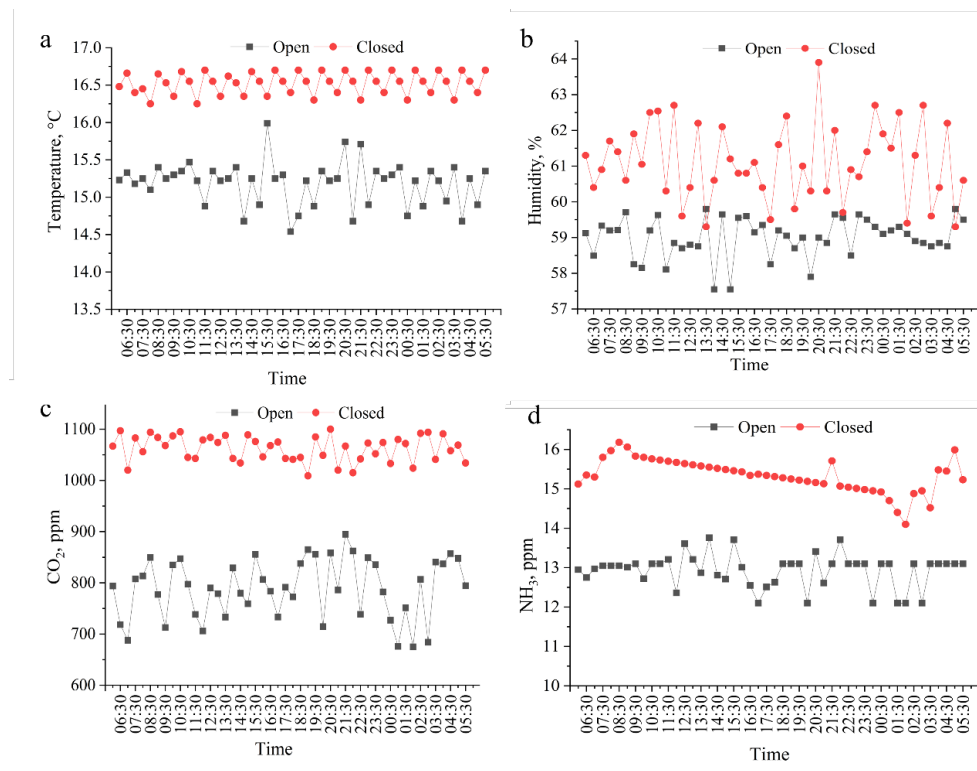


Figure 4. Hourly monitoring of environmental parameters: (a) temperature, (b) humidity, (c) CO_2 , and (d) NH_3 recorded in closed and open poultry housing systems during an experimental day in January 2025

Relative humidity data (Figure 4b) demonstrate greater stability in the closed housing system – indicating higher microclimatic control – whereas humidity levels in the open system were strongly influenced by external ambient conditions. Carbon dioxide concentrations (Figure 4c) followed similar daily patterns in both systems; however, the closed system showed higher but more stable CO₂ levels, while the open system exhibited greater temporal fluctuations. Ammonia concentrations (Figure 4d) were consistently higher in the closed housing system – primarily due to reduced ventilation and a higher likelihood of gas accumulation. In contrast, NH₃ levels in the open system showed greater variability – reflecting natural dilution through unrestricted air exchange.

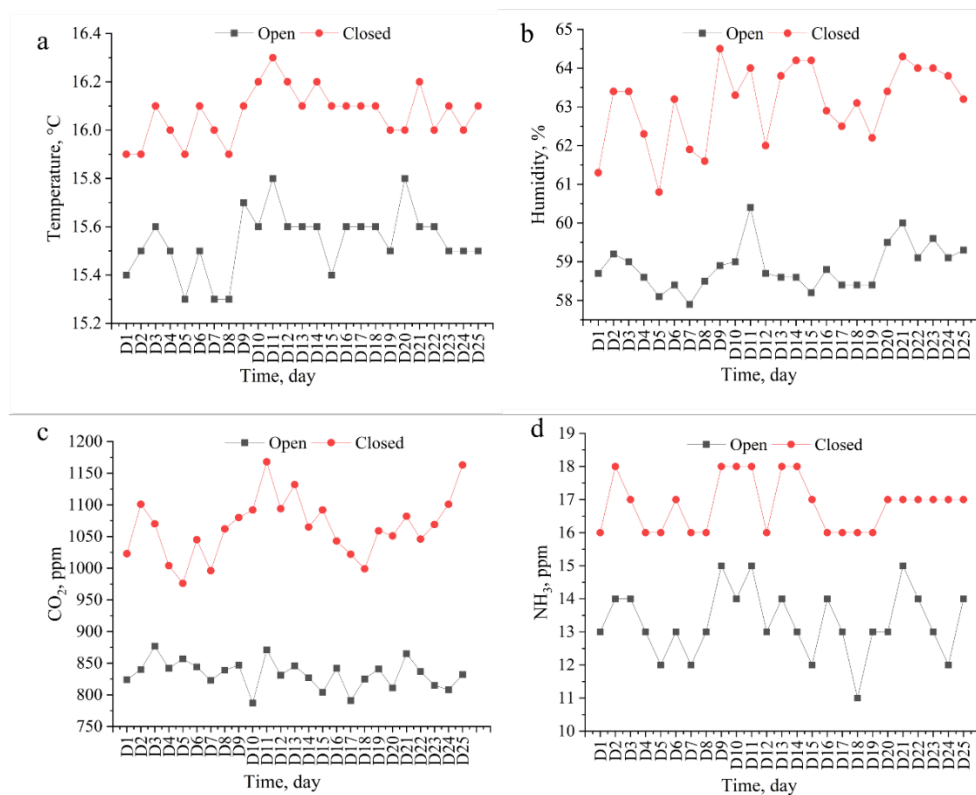


Figure 5. Daily monitoring of environmental parameters: (a) temperature, (b) humidity, (c) CO₂, and (d) NH₃ recorded in closed and open poultry housing systems during the study period

Although the closed housing system effectively maintained a stable microclimate, continuous monitoring of air quality remains essential – particularly to prevent excessive accumulation of harmful gases. The observed environmental stability in the closed system supports

improved bird welfare and productivity – highlighting the importance of controlled housing conditions in poultry production.

Figure 5 presents the daily trends of temperature, humidity, NH_3 , and CO_2 over the entire experimental period. The closed housing system exhibited substantially lower day-to-day variability in temperature and relative humidity – confirming the effectiveness of insulation and mechanical environmental control. In contrast, the open system showed pronounced fluctuations – due to direct exposure to changing ambient conditions. Relative humidity in the closed system remained within a narrower range – indicating improved moisture balance – which was positively associated with egg production. Although NH_3 and CO_2 concentrations were consistently higher in the closed system, their relative stability suggests that targeted improvements in ventilation could further enhance air quality – without compromising microclimatic uniformity.

Overall, the closed housing system provided a more stable microclimate – reducing environmental stress, improving welfare, and supporting higher productivity in laying hens.

Comparison between closed and open poultry housing systems

Table 1 summarizes the comparison of temperature, relative humidity, NH_3 , and CO_2 concentrations between the closed and open poultry housing systems. Statistically significant differences were observed for all measured parameters. The average relative humidity was higher in the closed system (63.09%) compared with the open system (58.85%). Mean air temperature was also slightly higher in the closed system (16.07°C) than in the open system (15.54°C) – which can be attributed to reduced heat loss resulting from insulation and limited air exchange with the external environment.

Ammonia concentrations averaged 16.84 ppm in the closed housing system and 13.28 ppm in the open system – reflecting the effects of reduced ventilation and gas accumulation in the closed environment. Similarly, CO_2 concentrations were higher in the closed system (1065.4 ppm) than in the open system (833.04 ppm) – further indicating differences in ventilation efficiency between the two housing types.

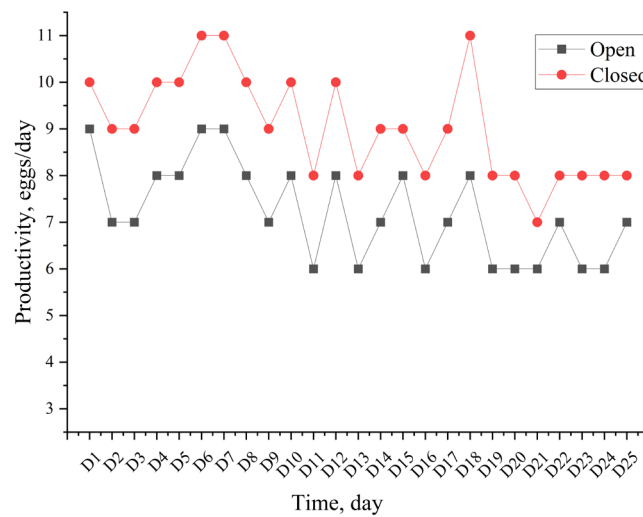
A key finding of this study is the effect of housing conditions on laying hen productivity. Egg production was significantly higher in the closed system – with an average of 9.04 eggs per day – compared with 7.2 eggs per day in the open system. The more stable temperature, humidity, and air quality in the closed housing system supported consistent laying performance, whereas environmental fluctuations in the open system adversely affected productivity. The observed difference was statistically significant ($T = 5.97$) – confirming the strong influence of environmental control on production outcomes.

Greater variability in temperature and humidity in the open system is known to negatively affect egg formation and shell quality – which may explain the higher occurrence of broken and undersized eggs under these conditions. Figure 6 illustrates daily egg production trends for both housing systems, while Figure 7 presents the correlation matrix among environmental parameters. A strong positive correlation was observed between relative humidity and both CO_2 and NH_3 concentrations ($r = 0.94$) – indicating close interactions among these microclimatic factors.

Table 1.

Comparison between the closed and open systems in measured parameters.

Parameter	System	Average	Median	Std. Dev.	Min	Max	T-test
CO ₂ (ppm)	Open	833.1	837	22.5	787	877	54.41*
	Closed	1065.4	1065	48.3	976	1168	
NH ₃ (ppm)	Open	13.28	13	1.1	11	15	13.71*
	Closed	16.84	17	0.8	16	18	
Temperature (°C)	Open	15.54	15.6	0.1	15.3	15.8	15.52*
	Closed	16.07	16.1	0.1	15.9	16.3	
Humidity (%)	Open	58.85	58.7	0.6	57.9	60.4	18.03*
	Closed	63.09	63.3	1.1	60.8	64.5	
Productivity (Eggs/day)	Open	7.2	7	1.04	6	9	5.97*
	Closed	9.04	9	1.13	7	11	

*Figure 6. Daily monitoring of egg production in closed and open poultry housing systems during the study period.*

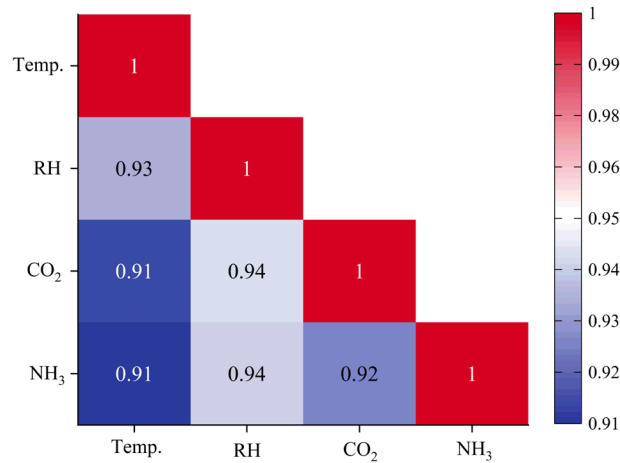


Figure 7. Correlation coefficient between the environmental parameters.

Conclusion

The findings demonstrate that the proposed IoT-based monitoring system effectively supports environmental control in poultry housing systems. The temperature, humidity, NH₃, and CO₂ levels were measured and quantified in both open and closed poultry housing systems every 5 minutes over 25 days of the experiment. A comparison between the two housing systems revealed that the closed housing system offers better control over all air quality parameters, thereby enhancing the hen's health status and performance in terms of feed efficiency and egg production. The use of IoT-enabled sensors for small and medium-scale poultry farms makes the practice not only affordable and accessible but also sustainable, hence minimizing economic losses that result from poor air quality. Further development and implementation of these technologies will aid in modernizing the practice of keeping poultry production up while supporting animal welfare and environmental sustainability. Future work may extend this IoT system to monitor additional gases such as H₂S and mixed combustible gases – including methane (CH₄), propane, LPG, hydrogen, and smoke – by incorporating sensors such as MQ-136 and MQ-2.

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MONITORING PARAMETRÓW ŚRODOWISKOWYCH W KURNIKACH Z WYKORZYSTANIEM IOT

Streszczenie. Wysokie stężenia gazów w kurnikach, w szczególności CO₂ i NH₃, może powodować u ptaków stres, zaburzenia oddychania, obniżenie produkcji jaj oraz zwiększoną podatność na choroby. W badaniu przedstawiono system monitorowania kluczowych parametrów środowiskowych w obiektach drobiarskich bazujący na technologii Internetu Rzeczy (IoT). System składa się z mikrokontrolera Arduino ESP32 oraz czujników DHT22, MQ-135 i MQ-137. Umożliwia on monitorowanie temperatury, wilgotności, stężenia amoniaku (NH₃) oraz dwutlenku węgla (CO₂) zarówno w zamkniętych, jak i otwartych systemach utrzymania kur niosek. Dane środowiskowe były gromadzone w chmurze, co pozwalało na zdalny monitoring kurnika w czasie rzeczywistym oraz dalszą analizę danych. Uzyskane wyniki wykazały, że systemy zamknięte są bardziej efektywne w regulacji temperatury i wilgotności przy jednoczesnym utrzymaniu stężeń gazów w dopuszczalnych granicach, co przekłada się na poprawę produkcji jaj. Zaproponowany system monitorowania wykorzystujący IoT stanowi praktyczne narzędzie wspomagające zarządzanie produkcją drobiarską oraz ograniczające straty wynikające z nieodpowiedniej jakości powietrza, przyczyniając się do zwiększenia efektywności produkcji.

Słowa kluczowe: IoT, ESP32, monitorowanie środowiska w chowie drobiu, CO₂, NH₃, temperatura, wilgotność.