Research Article

Design, Fabrication and Evaluation of a Portable Smart Alarm Device for Monitoring Environmental Conditions Affecting Respiratory Health in Poultry

Ahmed A. Al-Salhi[1*], Mokhtar J. Naser[2] and Hussam A. Majeed[2]

[1]Department of Pharmaceutical Sciences, College of Pharmacy, University of Thi-Qar, Iraq; [2]Department of Anatomy, Histology, and Embryology- College of Veterinary Medicine- University of Shatrah- Iraq

Abstract | A portable smart alarm system was designed and manufactured to monitor harmful gases (NH_3, CO_2, CO, H_2S) and environmental factors (temperature, humidity, air speed) in poultry houses. The system uses an Arduino platform, with real-time display, µSD card recording, data transfer via Wi-Fi, and an audible alarm when permissible values are exceeded. The system was field tested on 100 broiler chicks for 35 days, and its readings were compared with commercial measuring devices. Statistical evaluation showed no significant variation among the measurements, confirming the device's accuracy and reliability. During the observation period, peak concentrations were detected for NH_3 (10.24 ppm), CO_2 (720.33 ppm), and hydrogen sulfide (0.59 ppm). In contrast, CO_2 reached its lowest value (0.81 ppm) following the shutdown of the gas incubator after the second week. Additionally, the minimum temperature (21.88 °C), lowest relative humidity (55.34 %), and maximum air velocity (0.26 m/s) were recorded. These findings demonstrate that the device serves as a dependable and efficient instrument for tracking environmental parameters and supporting poultry welfare.

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***Correspondence** | Ahmed A. Al-Salhi, Department of Pharmaceutical Sciences, College of Pharmacy, University of Thi-Qar, Iraq; **Email:** ahmed-alsalhi@utq.edu.iq
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Introduction

Respiratory diseases are among the biggest challenges facing the poultry industry, especially broiler farms worldwide. These diseases negatively impact the quality of meat production. Unstable environmental conditions or high levels of harmful gases (NH_3, CO_2, CO, H_2S), in addition to disturbances in temperature, humidity, and air velocity inside poultry halls, significantly contribute to the exacerbation of these diseases, causing damage to the mucous membranes, thus weakening the immune defenses and increasing the susceptibility to respiratory diseases. This leads to significant economic losses in the poultry industry (Kang *et al.*, 2020; Li *et al.*, 2025).

The most prominent environmental factors affecting respiratory health in birds are ammonia (NH_3), which is released from the decomposition of poultry droppings. Concentrations of more than 25 ppm irritate the mucous membranes and lead to bronchitis, which contributes to respiratory infections (Bist *et al.*, 2023).CO_2 is also an effective indicator of poor ventilation in poultry farms. Elevated CO_2

concentrations reduce oxygen availability, potentially leading to respiratory stress, impaired growth, and increased mortality. Poultry industry companies recommend levels below 3,000 ppm in production farms (Pereira *et al*., 2023). CO_2 is also produced by incomplete fuel combustion resulting from the use of gas incubators in the early stages of chick rearing, causing respiratory toxicity that negatively impacts overall poultry health (Breurec *et al*., 1999).

H_2S is a toxic gas emitted by the decomposition of organic matter in bedding and poultry manure. Concentrations as low as one part per million have been observed to cause severe respiratory irritation in poultry (Vorobel *et al*., 2023). High relative humidity encourages the growth of microorganisms, ultimately leading to increased NH_3 emissions. Unsuitable temperatures also weaken the immune system, making it susceptible to respiratory infections. Researchers recommend good ventilation, which is essential to limit or reduce the accumulation of harmful gases and humidity, as poor ventilation leads to deteriorating air quality and increased stress on the respiratory system (Liu *et al*., 2020; Martinez *et al*., 2023; Al-Salhi, 2026).

Some recently published articles have focused on the weaknesses of current monitoring devices used in poultry farming. These researchers identified the reasons as being the lack of calibration of these devices before use, or their sensors having a limited range, as well as the inability of some of them to provide real-time data while measuring environmental conditions. For example, Lashari *et al*. (2018) developed a wireless sensor network for measuring temperature, humidity, and gases such as carbon dioxide and NH_3; however, it did not provide a comprehensive and real-time environmental assessment. Pereira *et al*. (2020) proposed an inexpensive monitoring device capable of handling specific environmental conditions within the farm. The system demonstrated acceptable results compared to commercial alternatives available in the market, but the device requires some development to be fully integrated.

Subsequently, Jabari *et al*. (2023) designed a Poultry-Edge-AI-IoT platform for real-time monitoring of temperature, humidity, and NH_3, integrating AI and IoT technologies. However, its ability to integrate and utilize data is limited. Finally, Putra and Waspada Putra (2023) developed a mobile IoT-based system using temperature and humidity sensors, in addition to an NH_3 gas sensor, providing real-time live monitoring. However, it excluded essential parameters such as CO_2 concentration and dust particle level.

Similarly, Lashari *et al*. (2023) demonstrated that the real-time integration and multi-indicator data still suffer from technical and cost limitations, in their study that focused on sustainable environmental control processes using the Internet of Things. Based on previous projects presented by researchers in the field of integrated environmental monitoring and the constraints they face, it became necessary to study these constraints and address them as much as possible, specifically in the field of poultry farming, to prevent respiratory diseases. Therefore, the current study aimed to design, manufacture, and test a portable smart alarm device to monitor environmental conditions affecting the health of the respiratory system in poultry. It targets the most prominent gases that cause respiratory problems for poultry, such as (NH_3, CO_2, CO, H_2S), in addition to humidity and temperature. It is intended for poultry farms, through which its notifications can be used to take the necessary preventive measures to reduce the respiratory problems facing this important sector.

Accordingly, this study hypothesizes that the manufactured portable smart alarm device can provide accurate, stable, and reliable real-time monitoring of harmful gases and key environmental parameters in poultry houses, with performance comparable to commercial devices. Therefore, the study seeks to determine whether the proposed system can effectively measure critical respiratory risk factors, including NH_3, CO_2, CO, H_2S, temperature, and humidity, under real field conditions.

Materials and Methods

This study was conducted to control respiratory diseases that often occur as a result of environmental changes within poultry production fields. The materials and methods included the following sections:

Integrated monitoring device design

Design and manufacture of a device consisting of an Arduino-based control platform connected to a set of sensors dedicated to measuring gases (NH_3, CO_2, CO, H_2S), and others to measure temperature, humidity, and air Speed. The device provides a display for instant readings, records data on a micro-SD card, and can be transferred wirelessly via Wi-Fi to a mobile phone or computer. An audible alarm is generated based on specific values taken from sensor calibrations. This alarm is triggered when the permissible limits are exceeded, according to the official technical specifications. The sensors were calibrated based on the manufacturer's data sheet, poultry farm conditions, and commercial calibration devices used in production fields. The device relies on a power supply and a 9000 mAh Li-ion 18650 battery, rechargeable via a USB-C port with intelligent power management. It supports charging from a 10–15 W solar panel to ensure continuous operation in a barn environment. Figure 1 illustrates the system designed to measure gas, temperature, humidity, and air speed.

Sensor calibration setup

Connect the device's sensors next to commercial measuring devices used in production fields, in different locations, at a height of 50 cm. Three sensors (three replicates) were installed for each type of sensor used in the device and the commercial devices. Figure 2 illustrates a simplified diagram of the sensor connection process.

Experimental setup and measurement protocol

This experiment was conducted to measure the level and stability of the above gas sensors. To test the readings of the manufactured integrated device, the experiment was carried out in November in Thi Qar Governorate, southern Iraq, on one-day-old broiler chicks with an average weight of 43 grams, with 100 chicks, for 35 days, in a hall designated for rearing, with dimensions of 10 m × 20 m × 3 m for length, width and height, respectively. All conditions for raising broiler chicks were provided according to the Broiler Management Guide (Aviagen, 2025), in terms of water, feed, health care, and ideal administrative conditions. A 7 cm thick wood shavings litter was used, and a gas incubator was deliberately used to ensure the release of some gases, specifically CO_2. The readings were recorded at 10:00 a.m. every week, with five readings for each of the studied indicators and according to the age of the birds (7, 14, 21, 28, and 35) days. Each indicator was read by three sensors in different locations (three replicates).To ensure accurate measurement; the last reading was recorded after the average body weight reached 2,500 g.

Figure 1: *System for measuring gas, temperature, humidity, and air speed*

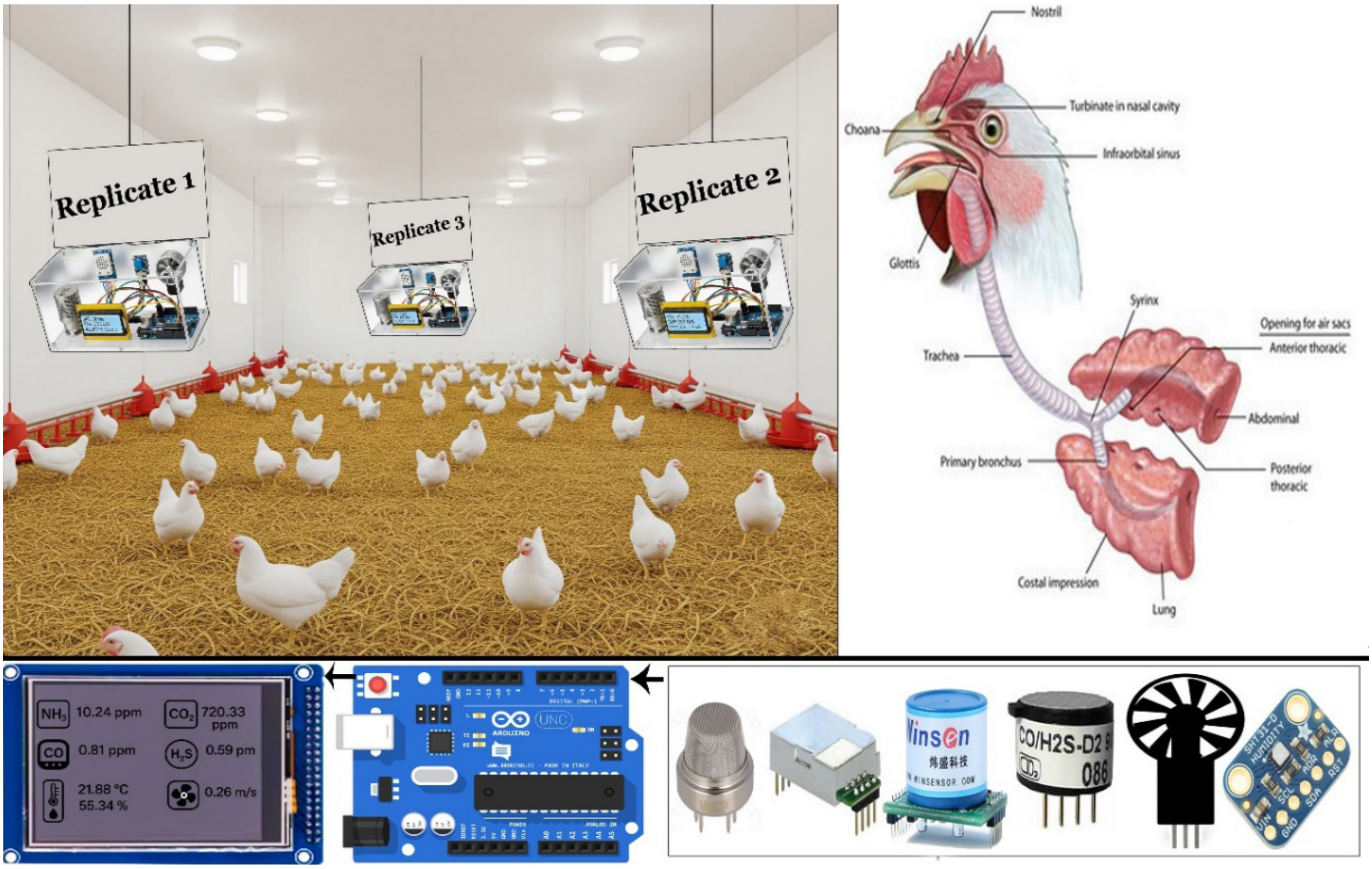


Figure 2: *Simplified diagram of the sensor connection process*

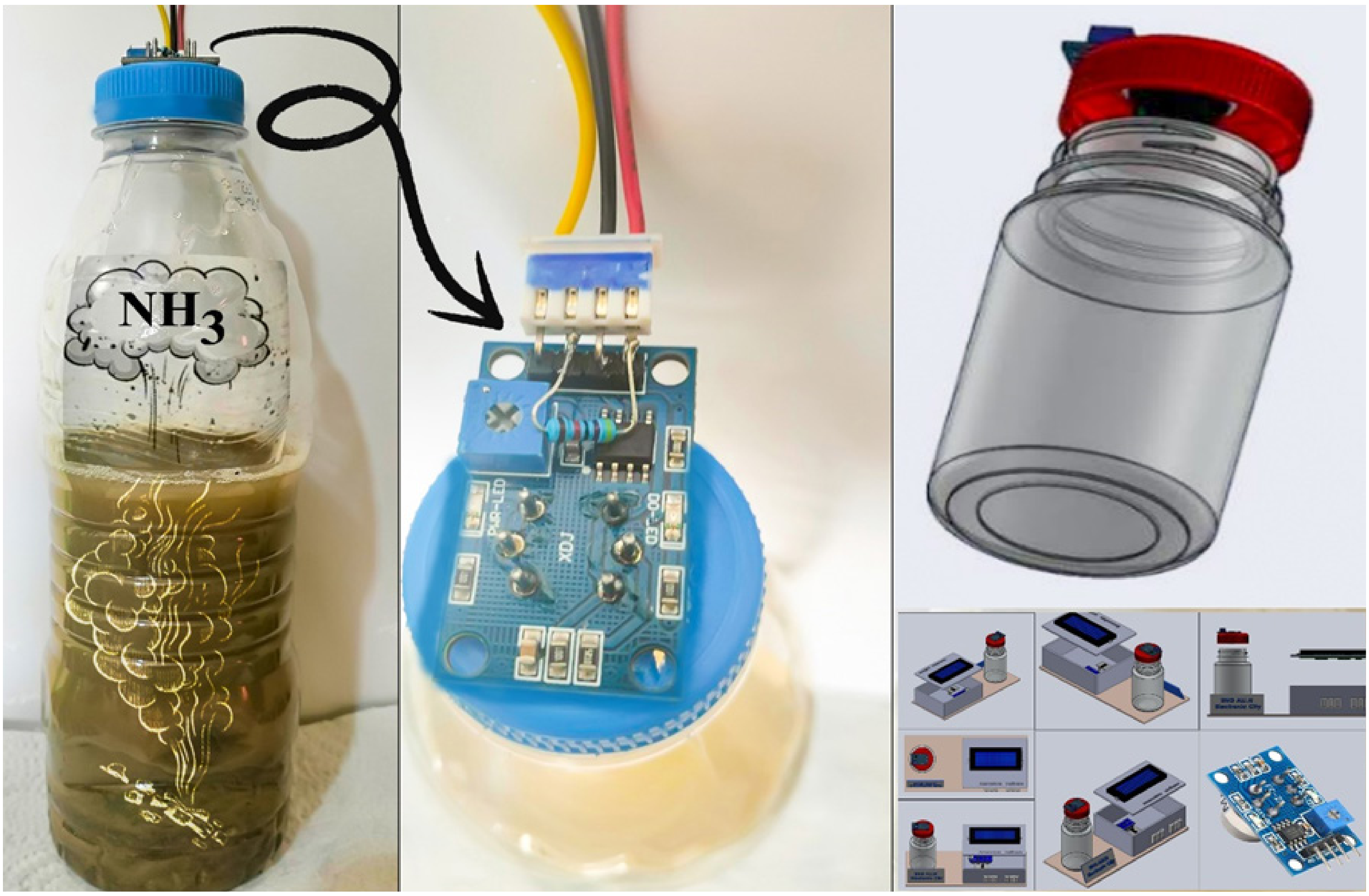


Figure 3: *Method for measuring the actual level of gas released from poultry droppings*

Direct gas measurement from droppings

A key feature of this system is the ability to directly attach sensors to isolated samples in special bottles to measure the actual level of gas released from bird droppings, as shown in Figure 3. This is considered very important for determining the level of gas emitted from bird droppings in experimental treatments during research studies, due to the use of protein-rich feeds.

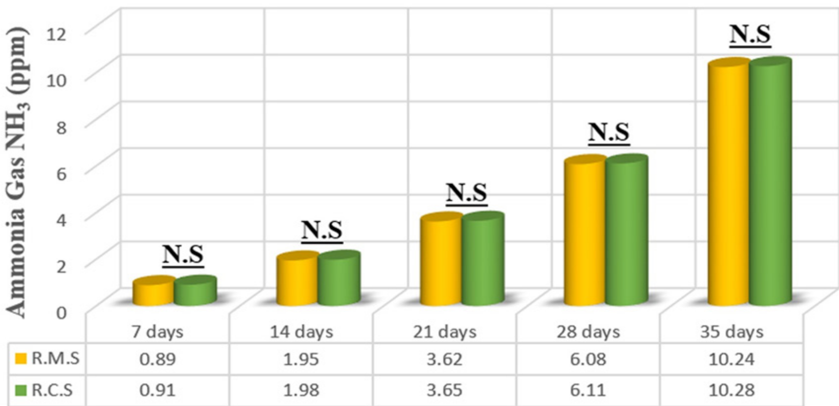
Statistical analysis

Data were analyzed using SPSS (2018), with mean differences evaluated by Duncan's test at 0.05 significance.

Results and Discussion

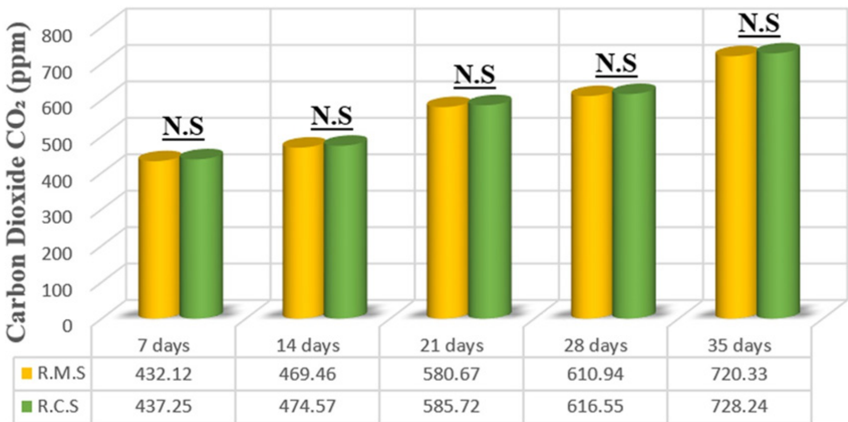
Comparison of the studied indicators between the manufactured device and other separate devices

The results of the study, as shown in Figures 4-10 represent the results compared the studied indicators, which included measuring concentrations of the harmful gases such as NH_3, CO_2, CO, H_2S, in addition to other environmental factors such as temperature, humidity, and air Speed. The results of the statistical analysis showed no significant differences between the studied indicators when comparing the results statistically using the Duncan test at a probability level ($P \le 0.05$) Comparing all readings of the manufactured device with those of the separate devices. Despite the presence of very slight statistical differences between the averages, which do not rise to the level of significance, these differences reflect slight differences in environmental conditions, as a result of the distribution of gas measuring sensors in different locations within the poultry hall, with three replications for each reading. To ensure higher accuracy in displaying results, the stability of the device's readings was monitored and ensured.



R.M.S: Reading the Manufacturer's sensor.
R.C.S: Reading the Commercial sensor.
N.S: No Significant.

Figure 4: *NH_3 gas indicators recorded by the manufacturer's device and various commercial devices*



R.M.S: Reading the Manufacturer's sensor.
R.C.S: Reading the Commercial sensor.
N.S: No Significant.

Figure 5: *Carbon dioxide indicators recorded by the manufactured device and various commercial devices*

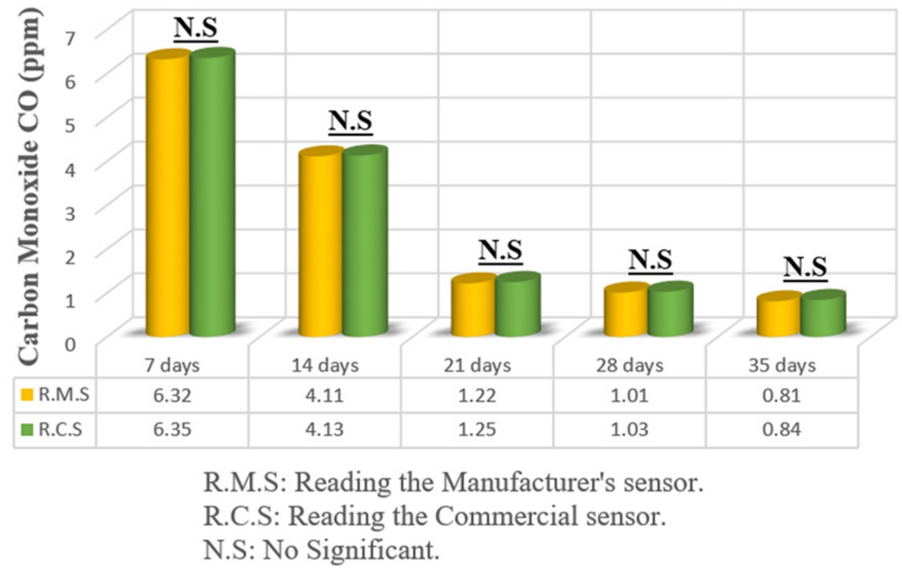


Figure 6: *CO_2 gas indicators recorded by the manufactured device and various commercial devices*

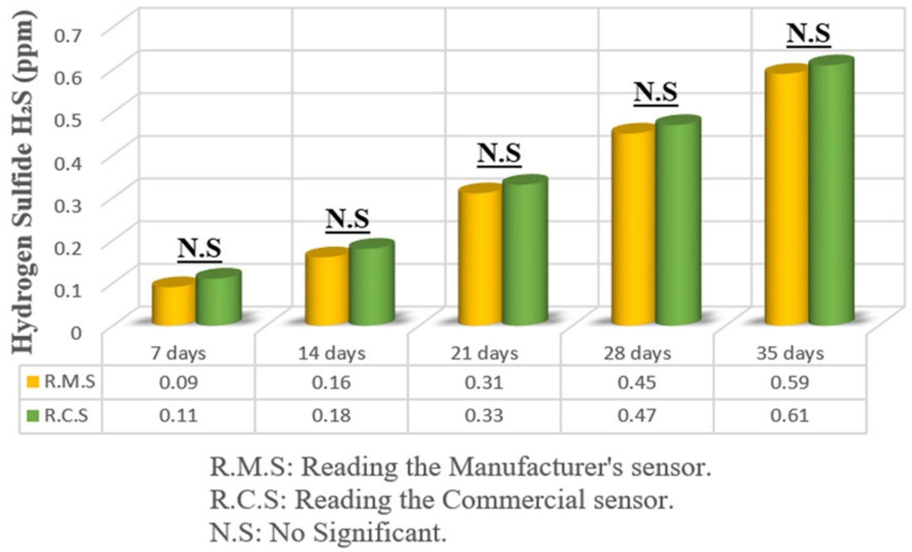


Figure 7: *Hydrogen sulfide gas parameters recorded by the manufactured device and various commercial devices*

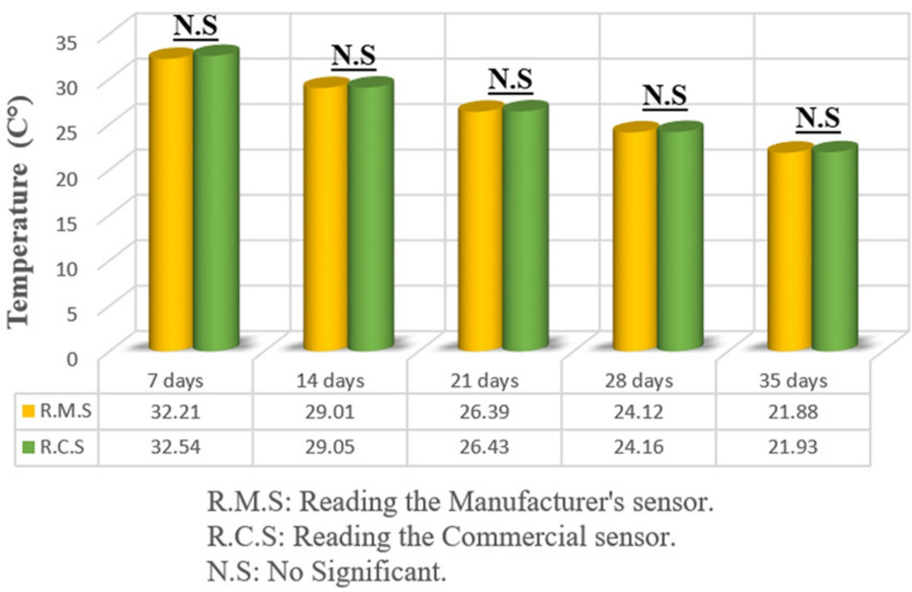


Figure 8: *Temperature indicators recorded by the manufacturer's device and various Commercial devices*

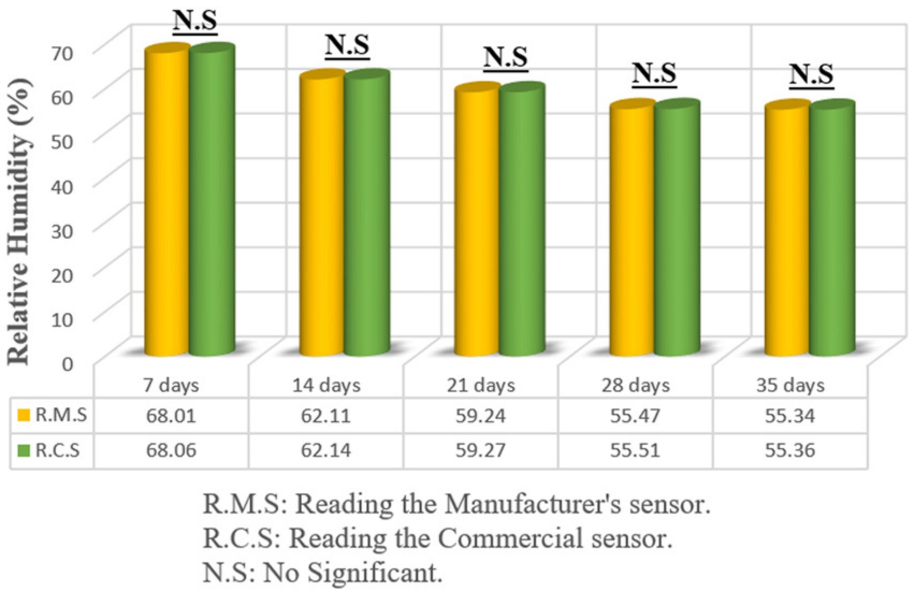


Figure 9: *Relative humidity indicators recorded by the manufacturer's device and various commercial devices*

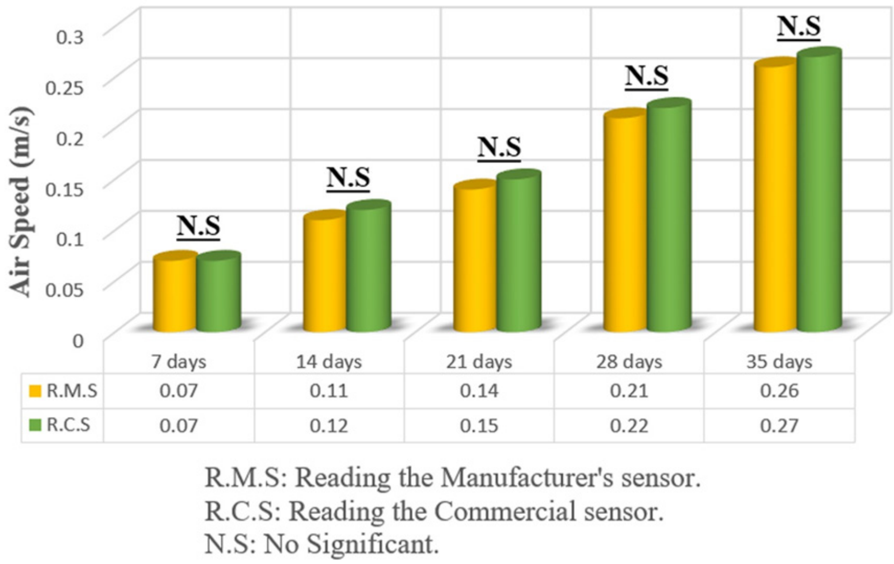


Figure 10: *Air speed indicators recorded by the manufacturer's device and various commercial devices*

The results of the studied indicators recorded by the sensors of the manufactured device were accurate, stable and within the global limits permitted in the environment of poultry production fields, as the manufactured device recorded the highest rate in some of the studied indicators: NH_3 gas, carbon dioxide and hydrogen sulfide, as they reached (10.24, 720.33, and 0.59) ppm, respectively, while the lowest rate was recorded for the CO_2 gas indicator, as it reached to 0.81 ppm, due to turning off the gas incubator, after the second week, which is considered the main reason for the increase in CO_2 emission, as it was turned off after the development of the thermoregulatory system and the completion of the feather parts of the birds, which contributed to the decrease in the rate of this toxic gas. The device also recorded the lowest rates of temperature (21.88°C) and relative humidity (55.34%), and the highest rate of air speed (0.26) m/s for the environmental conditions of birds raised inside the poultry hall at the age of 35 days.

The results of the device's readings were within global standards for poultry farms free of respiratory diseases, according to previous studies (Breurec *et al*., 1999; Liu *et al*., 2020; Pereira *et al*., 2023; Bist *et al*., 2023; Vorobel *et al*., 2023; Martínez *et al*., 2023). The demonstration was based on comparing the device's readings with commercial devices and evaluating the birds' vital signs. Maintaining the concentration of gases in the breeding environment within ideal physiological limits keeps the birds' blood parameters stable, which positively impacts oxygen levels and other biochemical parameters that are important for the health of the respiratory system. This stability allows oxygen to reach the tissues efficiently via hemoglobin, while providing the necessary energy for the respiratory muscles and maintaining respiratory function without stress or damage. As a result, the likelihood of infection is reduced. Chronic respiratory problems, which positively affect growth rates, feed conversion efficiency, and production yield of poultry (Sa *et al*., 2018; Al-Salhi and Al-Shatty, 2023; Al-Salhi, 2025).

Conclusions and Recommendations

It is concluded that the manufactured device is accurate and stable in measuring gases and environmental factors within poultry halls. All recorded values were within the internationally recommended limits, with no significant differences observed compared to commercial devices, reflecting the high reliability of the performance and efficiency index. This confirms the device's reliability in periodic environmental monitoring of poultry farms. It is recommended to use it in breeding environment management programs to improve productivity.

The stability of environmental indicators, resulting from proper bird management, also contributed to maintaining the efficiency of the respiratory system and bird health. Good ventilation and controlled humidity and temperature are the first line of defense against the accumulation of these gases.

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Novelty Statement

This study presents the design and fabrication of a low-cost, portable smart alarm device that simultaneously monitors harmful gases and key environmental parameters within poultry houses through an integrated real-time sensing, data logging, and wireless transmission system. It is comprehensive field validation against commercial instruments, supported by statistical analysis confirming its accuracy and reliability, thereby offering a practical and scalable solution for enhancing respiratory health monitoring and poultry welfare.

Author's Contribution

Ahmed A. Al-Salhi: Conceived the research idea, supervision, drafting and scientific structuring.
Mokhtar J. Naser: Designed and data collection for this research.
Hussam A. Majeed: Performed the statistical analysis and comparative. In addition, English language editing and preparation of the manuscript.

Generative AI and AI-assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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