

Portable detector prototype for monitoring temperature, humidity, and ammonia gas in broiler chicken coops based on Arduino Nano

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Abstract. Environmental monitoring in broiler chicken houses is crucial for maintaining animal health, productivity, and welfare. Temperature, humidity, and ammonia gas are key parameters affecting poultry performance, with excessive ammonia levels posing serious risks to both chickens and farm workers. This study presents the design and implementation of an Arduino Nano-based portable detector to monitor these parameters in real-time. The device uses DHT22 sensors for temperature and humidity, and an MQ-137 sensor for ammonia gas detection. Data is processed by the Arduino Nano and displayed on an OLED display. Test results show that the temperature sensor achieved satisfactory accuracy with an average absolute error of 1.4°C, the humidity sensor exhibited variability with an average error of 3.7%, and the ammonia gas sensor showed the greatest limitations with an average absolute error of 3.9 ppm. This portable detector has proven to be effective, economical, and easy to use for monitoring environmental conditions in broiler houses. With real-time monitoring, farmers can maintain air quality, improve chicken welfare, and support productivity.

1 Introduction

The poultry industry is one of the fastest-growing sectors in Indonesia, contributing significantly to the national food supply and economy [1]. However, maintaining optimal environmental conditions in broiler chicken coops remains a key challenge, as parameters such as temperature, humidity, and ammonia gas concentration directly influence the health, growth rate, and feed efficiency of chickens [2] [3]. Excessive ammonia, which originates

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from the decomposition of uric acid in chicken manure, poses a major problem when its concentration exceeds 20 ppm, potentially causing respiratory irritation, corneal damage, and decreased productivity [3] [4]. Similarly, poor ventilation and unstable temperature-humidity conditions increase stress levels in poultry, leading to reduced immunity and higher mortality [5].

To overcome these issues, environmental monitoring systems have been developed using microcontroller and IoT-based technologies. Previous studies have utilized Arduino Mega, Node MCU, and ESP8266 platforms integrated with DHT and MQ series sensors for automatic detection and data logging of temperature, humidity, and ammonia gas levels in poultry environments [2] [5] [6] [7]. However, such systems often depend on stable internet connectivity and fixed installations, limiting their use in small-scale or rural farms with minimal infrastructure [1] [8]. Additionally, commercial monitoring devices are typically expensive, making them inaccessible to independent farmers [4].

Therefore, this research aims to develop a portable environmental monitoring device that can measure temperature, humidity, and ammonia gas levels in broiler chicken coops using an Arduino Nano microcontroller. The proposed system integrates a DHT22 sensor for temperature and humidity measurement and an MQ-135 sensor for ammonia detection. Data are processed by the Arduino Nano and displayed on an OLED screen for direct, real-time observation without internet dependency. This approach combines the low cost and accuracy of open-source hardware with the mobility and simplicity of portable operation, enabling efficient environmental assessment at multiple points within a coop. Compared to previous IoT-based monitoring studies [2] [5] [8], the proposed system emphasizes portability, energy efficiency, and direct field usability, offering an affordable and reliable solution for small to medium-scale poultry farms.

2 Materials and Methods

The development of a portable detector for monitoring temperature, humidity, and ammonia gas in broiler chicken coops was carried out using an Arduino Nano microcontroller as the central controller. The design followed a functional structure consisting of input, processing, and output sections, ensuring that the system could continuously collect, analyze, and display environmental data in real time. This methodological framework was adapted from prior IoT-based environmental monitoring studies [1] [2] [5] [6].

On the input side, two sensors were utilized. The first was the DHT22 digital sensor, which is widely used in environmental monitoring due to its relatively high accuracy and stability compared to the DHT11. The DHT22 provides two essential parameters: air temperature, measured in degrees Celsius ($^{\circ}\text{C}$) with a range of -40°C to $+80^{\circ}\text{C}$ and an accuracy of $\pm 0.5^{\circ}\text{C}$, and relative humidity, measured in percentage (%RH) with a range of 0–100% and an accuracy of ± 2 –5%. The second input device was the MQ-137 gas sensor, specifically designed for detecting a variety of harmful gases, including ammonia (NH_3), benzene, and carbon dioxide. In this system, the MQ-137 was calibrated to focus on ammonia gas concentration, expressed in parts per million (ppm), with a typical detection range between 5 and 200 ppm. These two sensors were selected because they directly address the most critical environmental factors in broiler chicken farming: excessive heat and humidity that may cause heat stress, and ammonia accumulation that can negatively affect chicken health and productivity [3] [4] [9].

The signals collected from the sensors were transmitted to the Arduino Nano, which served as the processing unit. The Arduino Nano is equipped with an ATmega328P microcontroller operating at 16 MHz, 32 KB of flash memory, and multiple digital and Analog input/output

pins. In this study, it was programmed to acquire data from the DHT22 and MQ-137 at predefined intervals, convert the raw signals into calibrated digital values, and compare them with the established threshold parameters. The thresholds were defined based on poultry farming standards, particularly an ammonia concentration limit of 20 ppm, above which health risks for chickens significantly increase, and temperature and humidity ranges considered optimal for broiler chicken growth [3] [10].

The output section consisted of multiple devices that presented processed information to users in an accessible manner. The OLED Display module was connected to the Arduino Nano via an I2C interface, simplifying wiring and reducing pin usage. This device provided a direct, real-time readout of temperature, humidity, and ammonia concentration inside the coop. A buzzer was also integrated as an early warning system, activated whenever a parameter exceeded its safe limit. All components were powered by a rechargeable 5V source, ensuring portability and allowing the device to be easily moved between different coop locations.

The block diagram (Figure 1) of the system illustrates the overall interaction between the hardware components and their respective functions. It consists of three main sections: the input, processing, and output units. The input unit includes the DHT22 and MQ-137 sensors that capture environmental parameters such as temperature, humidity, and ammonia concentration. These signals are then transmitted to the Arduino Nano, which serves as the processing center responsible for data acquisition, conversion, and decision-making. The processed data are subsequently delivered to the output unit, which includes the OLED display for real-time visualization and the buzzer as an alert mechanism when abnormal conditions are detected. This diagram provides a clear overview of the system's functional relationships and how each component contributes to real-time environmental monitoring inside the broiler chicken coop.

The system architecture diagram provides (Figure 2) a more detailed representation of both the hardware and software integration within the device. It demonstrates how the sensors interface with the Arduino Nano through analog and digital pins, and how the processed data are managed and displayed. Power management is also shown in this diagram, illustrating the use of a rechargeable 5V supply to ensure the portability of the system. The architecture diagram highlights the modular design approach, making it possible to expand or modify the system—for instance, by adding wireless communication modules or data logging capabilities in future developments.

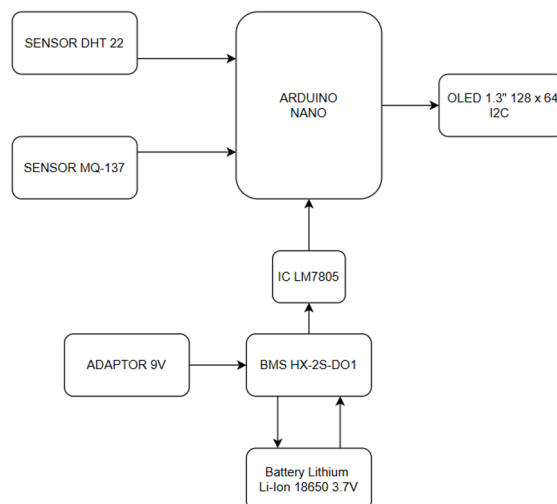


Fig. 1. Block Diagram System

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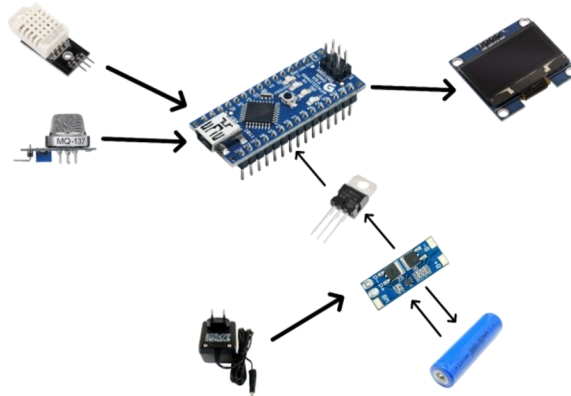


Fig. 2. Hardware Design

The sequential operational logic of the system is further described in the flowchart (Figure 3). The process begins with system initialization, during which the Arduino Nano configures sensor libraries and prepares memory for data storage. Once initialization is complete, the DHT22 and MQ-135 sensors continuously acquire environmental data, which are then processed into standard units: temperature in $^{\circ}\text{C}$, relative humidity in %RH, and ammonia concentration in ppm. The results are immediately displayed on the OLED, and at the same time, the Arduino Nano evaluates whether the measured values exceed the critical thresholds. If ammonia exceeds 20 ppm or the temperature and humidity values deviate from the optimal range, the buzzer is triggered as an alarm to notify farmers of potential risks. After this evaluation, the system loops back to acquire new data, forming a continuous and automated monitoring cycle.

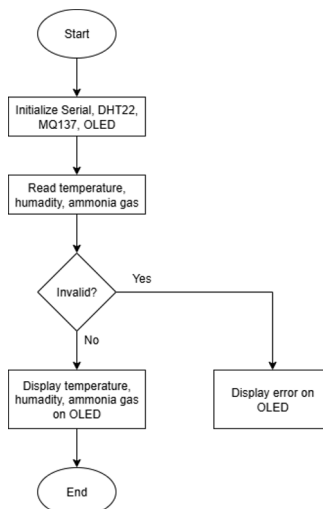


Fig. 3. Flowchart System for Microcontroller

To ensure reliability and validate sensor accuracy, the prototype was tested against calibrated reference instruments, including a standard thermometer, hygrometer, and ammonia gas detector. The accuracy evaluation employed a percentage error calculation, which was computed using Equation (1):

$$\text{Percentage Error (\%)} = \frac{|\text{Measured Value} - \text{Reference Value}|}{\text{Reference Value}} \times 100 \quad (1)$$

Where:

Measured Value = reading obtained from the prototype sensor.

Reference Value = reading obtained from the standard instrument.

In equation (1), the Measured Value represents the reading obtained from the prototype sensor, while the Reference Value refers to the measurement obtained from a calibrated instrument. The absolute value ensures that the error is always positive, providing a fair measure of accuracy regardless of overestimation or underestimation. This calculation was applied for each trial, and the overall accuracy of the sensors was summarized using the Mean Absolute Error (MAE). As an example, in Trial 1 of temperature testing, the DHT22 measured 25.4 °C compared to the reference thermometer at 27.5 °C, resulting in a percentage error of 7.64%. By repeating this process across all trials, a comprehensive accuracy profile of the system was obtained.

To validate the accuracy of the prototype, all sensor readings were compared against calibrated reference instruments. For temperature and humidity, the HTC-2 Clock Thermometer and Hygrometer was used as reference devices, providing stable and accurate measurements of ambient conditions in °C and %RH, which served as the benchmark for evaluating the DHT22 sensor. For ammonia concentration, the AR8500 Ammonia Gas Detector (Smart Sensor AR-8500 NH₃ Tester) was employed as reference device, offering high sensitivity and reliable ppm readings as a standard reference for the MQ-135 gas sensor. These reference instruments ensured that the evaluation of percentage error was based on precise and trusted values, thereby enhancing the credibility of the performance assessment of the portable monitoring system.

Finally, all components were assembled into a compact 3D-printed enclosure designed to protect the sensors from dust and debris while maintaining portability and ease of deployment at different monitoring points within the coop. Field testing was carried out in a real broiler chicken environment to verify the robustness of the device under practical conditions. The collected data were compared with reference values, confirming the accuracy, durability, and feasibility of the system for continuous poultry farming applications.

3 Results and Discussion

The physical realization of the system, as shown in Figure 3 (Portable Detector Prototype), successfully addresses the need for a portable and field-ready device, thereby fulfilling one of the key objectives stated in the Introduction—to overcome the limitations of stationary monitoring systems. The device is enclosed in a compact, 3D-printed housing (likely manufactured using Fused Deposition Modelling), which facilitates easy handling and rapid deployment at different monitoring points within a broiler coop. In terms of functionality, the integration of a small local display (OLED) enables immediate and real-time user interaction. This allows farmers to directly access critical environmental metrics—temperature, humidity, and ammonia—without relying on external computing devices or unstable wireless networks, thus ensuring fast and reliable feedback. While the physical design enhances flexibility and ease of use, which are essential for practical farm applications, the system's

overall effectiveness remains dependent on the ability to correct the inherent inaccuracies of the sensors, particularly the significant systematic error identified in the ammonia gas sensor.

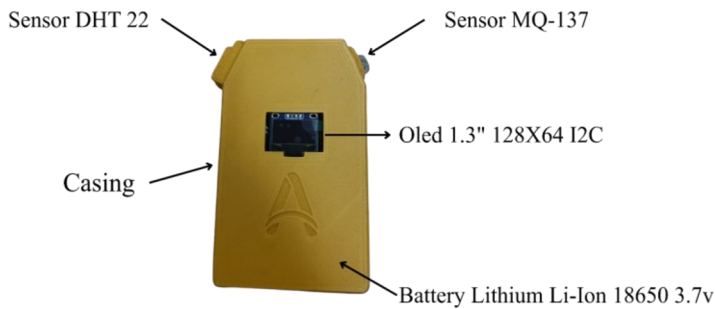


Fig. 4. Prototype Portable Detector

3.1 Basic Function Testing

Initial testing confirmed that all components of the system functioned as expected. The sensors were able to provide readings, and the Arduino Nano successfully processed and displayed the values on the OLED display. Data were also consistently updated in real-time, meeting the requirement for continuous monitoring in poultry environments.

3.2 Performance Testing

Initial testing confirmed that all components of the system functioned as expected. The sensors were able to provide readings, and the Arduino Nano successfully processed and displayed the values on the OLED display. Data were also consistently updated in real-time, meeting the requirement for continuous monitoring in poultry environments.

3.2.1 Temperature Sensor

The temperature sensor showed satisfactory accuracy with a mean absolute error of 1.4 °C compared to the reference instrument. Most measurements differed by less than 2.5 °C, while the maximum deviation was 3.9 °C (Trial 1). This relatively small discrepancy is acceptable for environmental monitoring in poultry houses, where recognizing temperature fluctuations and trends is more critical than achieving precise point measurements. Thus, the temperature monitoring function of the prototype can be considered sufficiently reliable for real-time applications.

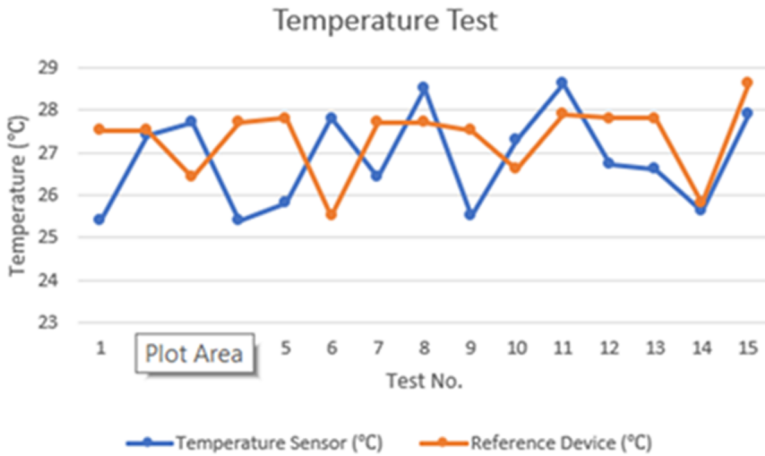


Fig. 5. Visualisation Experimental Result of Temperature Test

Table 1. Test Results of The Temperature Sensor and and Reference Device

Test No.	Temperature Sensor (°C)	Reference Device (°C)	Percentage Error (%)
1	25.4	27.5	7.64
2	27.4	27.5	0.36
3	27.7	26.4	4.92
4	25.4	27.7	8.30
5	25.8	27.8	7.19
6	27.8	25.5	9.02
7	26.4	27.7	4.69
8	28.5	27.7	2.89
9	25.5	27.5	7.27
10	27.3	26.6	2.63
11	28.6	27.9	2.51
12	26.7	27.8	3.96
13	26.6	27.8	4.32
14	25.6	25.8	0.78
15	27.9	28.6	2.45

3.2.2 Humidity Sensor

The humidity sensor produced more variable results, with a mean absolute error of 3.7%. Although the majority of readings showed low deviation ($\leq 3\%$), several trials exhibited significant anomalies, including errors of 9% (Trial 2) and 20% (Trial 8). Such inconsistencies reduce confidence in the sensor’s robustness, especially in harsh and humid poultry environments where accurate humidity measurement is critical, as uncontrolled humidity accelerates ammonia production. Potential causes of this variability include sensor drift, contamination from dust or waste particles, and limited dynamic range. Therefore, while the humidity sensor is functional, its performance is less consistent than the temperature sensor.

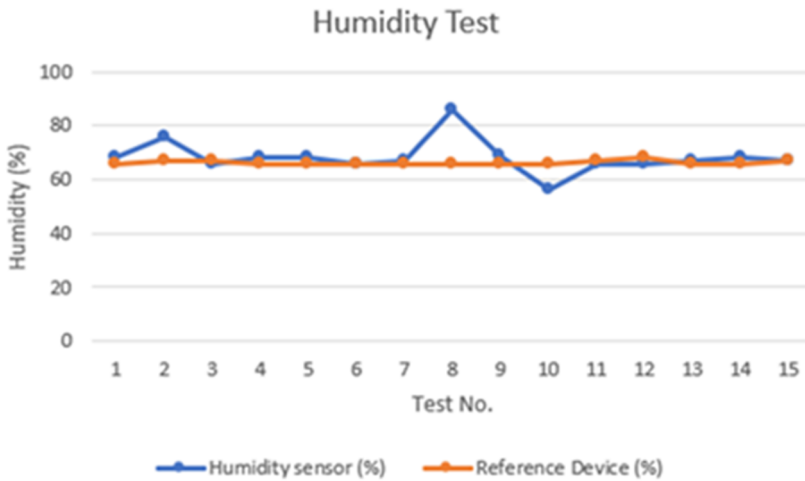


Fig. 6. Visualisation Experimental Result of Humidity Test

Table 2. Test Results of The Temperature Sensor and and Reference Device

Test No.	Humidity sensor (%)	Reference Device (%)	Percentage Error (%)
1	68	66	3.03
2	76	67	13.43
3	66	67	1.49
4	68	66	3.03
5	68	66	3.03
6	66	66	0
7	67	66	1.52
8	86	66	30.30
9	69	66	4.55
10	56	66	15.15
11	66	67	1.49
12	66	68	2.94
13	67	66	1.52
14	68	66	3.03
15	67	67	0

3.2.3 Ammonia Gas Sensor

The ammonia gas sensor was tested against the AR8500 Ammonia Gas Detector to evaluate its accuracy. As shown in Table 3, the prototype readings ranged from 4.00 to 6.35 ppm, while the reference device measured 4.30 to 6.20 ppm. The calculated percentage errors varied between 2.42% and 10.45%, with an average error of 6.8%. These results indicate that the MQ-137 sensor provides sufficiently accurate readings for ammonia detection in broiler coops, with deviations likely caused by humidity effects and sensor response lag. Overall, the prototype demonstrates acceptable accuracy for practical environmental monitoring applications.

Table 3. Test Results of Ammonia Gas Sensor and Reference Device

Test No.	Ammonia Gas Sensor (ppm)	Reference Device (ppm)	Percentage error (%)
1	4.86	4.4	10.45
2	4.6	4.3	6.98
3	6.35	6.2	2.42
4	5.68	5.3	7.17
5	4	4.3	6.98

4 Conclusion

The development of a portable detector for monitoring temperature, humidity, and ammonia gas in broiler chicken coops based on Arduino Nano has been successfully realized. The physical prototype demonstrated practicality and portability through its compact 3D-printed casing and integrated local display, enabling farmers to obtain real-time environmental data without relying on external devices. Performance testing indicated that the temperature sensor provided sufficiently reliable results with minor deviations acceptable for poultry monitoring applications. However, the humidity sensor exhibited higher variability, including significant anomalies that reduced its robustness in harsh coop environments. More critically, the ammonia gas sensor displayed a consistent positive bias with substantial systematic errors, making it unreliable for accurate detection at safety thresholds.

Overall, while the prototype fulfills the objectives of portability and basic real-time monitoring, further improvement is required, particularly in the calibration and selection of sensors, to ensure accurate and dependable ammonia detection. Future work should focus on refining sensor algorithms, improving environmental resilience, and integrating wireless communication for broader monitoring capabilities.

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