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Improving the Productivity of Laying Hens Through a Modern Cage Cleanliness Monitoring System that Utilizes Integrated Sensors and IoT Technology

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***Abstract*—Animal husbandry plays a crucial role in the Indonesian economy. One example is layer farming. The cage's environmental conditions can have an impact on the health of laying hens, including factors like temperature, humidity, and the presence of ammonia gas. This research aims to support chicken farmers in identifying and monitoring the environmental conditions surrounding their chicken coops, with the goal of enhancing the productivity of laying hens. This study is organized using a prototype development approach. The proposed system utilizes Arduino UNO as a microcontroller, ESP32 as a connecting node from hardware to software, MQ-135 sensor as an ammonia gas sensor, DHT-22 sensor as a temperature and humidity sensor, and 16×2 I2C LCD to display the collected data. WIFI connected web monitoring system built with Laravel, MySQL, and Bootstrap. An improvement to the existing system is the integration of an ammonia gas odor sensor calibrated against clean air as a reference. Testing was conducted for a continuous period of 7 days. Comparison of test results is performed with existing devices to observe the difference in measured values. The measurement result demonstrates a remarkable ability to accurately measure temperature, humidity, and ammonia levels in the air. The difference with the comparable device was about 2%. Meanwhile, the monitoring dashboard for IoT functional monitoring operates effectively, allowing chicken farmers to efficiently analyze the cleanliness of their chicken coops. All measurement parameters are conveniently recorded in the form of tables and graphs, providing valuable information.**

Keywords*—Monitoring System; Laying Hens; Environmental Monitoring; Animal Husbandry; Ammonia Gas; Research and Development; Prototype; Internet of Things; IoT; DHT-22; MQ-135.

I. Introduction

Livestock plays a crucial role in driving the Indonesian economy. As mentioned in [1], the livestock subsector, particularly poultry, plays a crucial role in the national economy and provides substantial employment opportunities. It is a reliable sector for boosting the overall economic growth [2].

One of the challenges faced by poultry farming companies is the unpredictable environmental conditions surrounding the cage. The suboptimal environmental conditions within the cage might have a detrimental effect on the health of laying hens, perhaps leading to a decrease in egg productivity [3]. Furthermore, an appropriate environmental conditions are crucial for ensuring the productivity of laying hens [4]–[6].

Several factors to consider are wind speed, lighting conditions, humidity levels, and temperature [7]–[10]. Temperature and humidity levels detection helps the farmers to monitor the environment condition level, since the high temperature influences eggshell quality [11] and behavioral response of the laying hens from heat stress [12]. In addition, another parameter that needs to be considered is the presence of gas produced from the chicken manure itself.

Measuring these parameters is essential for maintaining a healthy and clean environment in a laying hen house [13]. During this time, farmers rely solely on their intuition to assess the cleanliness of the layer cages by observing the amount of manure present, without closely monitoring temperature and humidity levels [14]. Occasionally, the levels of ammonia gas emitted from the manure can surpass the established health threshold without awareness [15]–[17]. Thus, to assist poultry farmers in enhancing the health of their laying hens, there is a requirement for a device that can identify the environmental conditions of the laying hen cage and remotely monitor its status, automatically record and analyze data [18].

The MQ135 sensor is commonly employed to detect gas levels emitted by chicken manure. The MQ135 sensor is highly effective in detecting gas levels in various chicken cages [19]. This is because the MQ-135 gas sensor is a chemical sensor that can detect a wide range of substances, including NH_3, NO_x, alcohol, benzene, smoke (CO), CO_2, and other compounds [20]. Furthermore, this sensor is frequently employed to measure the air quality indices [21] both for outdoor and indoor environments [22].

Other variables considered are the ambient temperature and humidity levels within the cage. The correlation between these two parameters has a significant impact on determining the circumstances surrounding the cage [23], [24]. The humidity range recommended for a specific space is depicted in Fig. 1, and it should be maintained within the range of 45% to 65% [25], [26].

Fig. 1 indicates that when humidity levels surpass 65%, an environment with insufficient humidity might foster the proliferation of fungi, bacteria, viruses, mites, and allergies. Conversely, when the humidity falls below 40%, it can lead to extremely dry air, which may potentially lead to respiratory diseases [27]–[30].

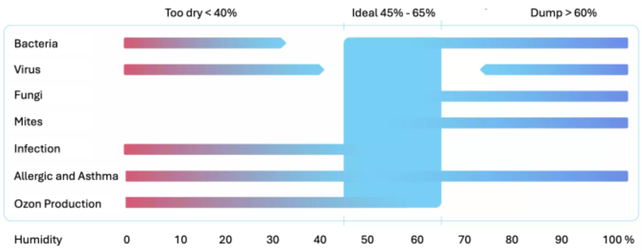

Fig. 1. Allowable range of humidity

Several studies have employed DHT11 sensors to assess humidity and temperature levels. Some researchers utilize these sensors to identify air pollution [31], [32]. Additionally certain devices are employed for monitoring plant temperature and humidity [33]. These sensors exhibit a high level of effectiveness and maintain consistent accuracy in measuring temperature and humidity [34].

The advancement of technology enables remote monitoring of systems from anywhere at any time. Thus, the proposed system will be gradually integrate with Internet of Things (IoT) technology, utilizing web-based utilizing web-based data entry to send high-quality, real-time data while ensuring optimal efficiency and effectiveness [35]–[38]. Within the field of animal husbandry, the online application allows for the monitoring of several recommended factors, such as temperature, humidity, and ammonia gas levels. This web application enables users to conveniently check the state of the enclosures from any web browser, obviating the necessity of physically visiting the cages [39], [40].

Based on the provided information, it is essential to observe environmental indicators using integrated sensors, such as temperature, humidity, and ammonia gas levels in the vicinity of the cage. One of the reasons that needs to be addressed as a gap is the lack of integration between existing equipment, gas sensors, and monitoring systems. This is crucial to ensure the health of hens and sustain consistent egg production. In order to accomplish this, it is necessary to develop an automated system that is based on the IoT. This technology will constantly monitor the environmental conditions in the cage and transmit useful information to the farmer through an LCD screen conveniently located within the cage or remotely over the web or mobile phone.

This research aims to create a real-time monitoring system for layer cages with IoT technology, and to assess its efficacy in tracking temperature, humidity, and levels of ammonia gas. This system will grant users access to monitor the environmental data via a website and allowing them to monitor temperature, humidity, and the presence of ammonia gas promptly and accurately in the surrounding area of the cage. Monitoring data is captured and analyzed using reports that use tables and graphs to illustrate the information. At the end of the investigation, the effectiveness of the detection technologies will also be assessed. Hence, the suggested approach will indirectly assist laying hen producers by offering additional alerts and assistance to enhance the health of their hens.

The remaining sections of this paper are structured as follows. Section 2 will provide a comprehensive explanation of the research and its methods. In Section 3 will delve into the testing procedure to ensure optimal performance of the system. Section 4 will presents the findings of the test analysis as conclusions.

II. Research and Methodology

A. Methodology

This research is explained through the prototype development methodology [41]. The initial step of this methodology involves conducting a comprehensive review of existing literature. The literature review examined relevant and similar studies on the remote monitoring of cage conditions by including sensors for measuring humidity, temperature, and ammonia gas level installed around the cage. Moreover, comprehensive study has been conducted on several categories of IoT dashboards that will be implemented into the proposed system. The next step involves evaluating and developing the proposed system design. At this stage, the design of the cage environment detection system involves strategically placing integrated sensors at various measurement points, and creating a comprehensive design and monitoring system including making prototypes that will be used in this research. The next stage involves system testing, where the system will be evaluated for its performance in actual environments. At this stage the system will be tested for data retrieval and compared to existing devices to evaluate its performance. The testing process will be carried out for several days to assess the daily data on parameter detection features. This will enable the display of test findings in the form of graphs or tables during the testing period. After the system test results are completed, a comprehensive analysis will be conducted to derive significant conclusions [42], [43].

B. Literature Review

After conducting a comprehensive analysis of the existing literature, several research have been initiated to improve hens' productivity. This detection device is proposed using Arduino Mega 2560 and MQ-135 sensors to measure ammonia gas levels and DHT-I1 sensors to measure air temperature and humidity [44]–[46]. This system demonstrates the effective functionality of these sensors. However, this research still has limitations as it only utilizes a single detection point and lacks integration with IoT.

Additionally, several studies have focused on the development of a system to monitor the temperature and humidity of chicken cages, with the goal of improving the productivity of broiler chickens [47]–[50]. This monitoring system utilizes a closed-house system and employs DS18B20 as temperature sensors, DHTI1 sensors as humidity sensors, and MLX90640 infrared sensors as chicken body temperature detectors [51], [52]. This system exclusively emphasizes the physiological cycle of broilers, excluding any consideration for the hens' layers.

Over the years, monitoring systems started to be integrated with room temperature detecting systems. The monitoring system in [53] utilizes the ESP8266 NodeMCU to transmit the DHT11 sensor reading data to the server. Blynk, an IoT software service provider, manages the data flow through its Application Programming Interface (API) [54]. A similar approach was also utilized in the research [55], [56] as a comparable technology. The study utilizes XAMPP web server as the storage system for the data collected from the sensors. The data from the sensor readings is transmitted wirelessly from the NodeMCU to the server, as employed in research [57]–[59].

In addition, some studies have utilized the Internet of Things (IoT) system [60]–[63]. This research utilizes the existing internet network and integrated DHT11 temperature and humidity sensors, solid state relays for heating and fan control, and the ESP8266 [64]. Similar with previous research, NodeMCU module acts as a microcontroller that processes and transmits data from sensors to the Blynk cloud server via the internet network [65]. This system has the capability to transmit data to the server and is specifically designed for a single observation point inside a cage [66].

According to the description provided, there is no device that combines a room condition detector and a comprehensive laying cage cleanliness detector with monitoring system capabilities. Currently, the previous study is limited to single measurement points and lacks a comprehensive approach. Hence, this research aims to develop a device that capable to measure temperature, humidity, and gas levels in the surrounding environment of a laying hen cage. The device will utilize the DHT22 sensor and the MQ135 sensor. Those device known for their stability and accuracy [65]. According to some research findings, it has been discovered that the DHT22 demonstrates superior accuracy compared to the DHT11. Specifically, the DHT22 exhibits a relative error of 4% in temperature measurement and 18% in humidity [67]–[69].

This research will utilize ESP32 data processors for data processing purposes. This is because the ESP32 has a greater number of pins, allowing for the incorporation of a multi input of GPIOs with a diverse array of functionalities [70]. Moreover, the ESP32 Wi-Fi module features improved velocity and is also compatible with Bluetooth compatibility [71], [72].

Meanwhile, the provider of the monitoring system interface for proposed system will utilize a web and Android-based platform, allowing farmers to conveniently monitor cage conditions from any location using their desktop or mobile phone. The supporting application for the monitoring system utilizes the Representational State Transfer Application Programming Interface or REST API. This API is responsible for performing functions and retrieving requested resources using the HTTP protocol [73]–[75].

MySQL is an RDBMS, which stands for Relational Database Management System. It is a sort of database management system that efficiently manages the relationship between tables. MySQL is built on a client-server design, which contributes to its high performance [76]–[78]. MySQL is utilized as a database management system that supports the storage of data in tables within the proposed system.

Bootstrap and Laravel are also utilized for a rapid and efficient framework [79]. Bootstrap is a CSS and Javascript framework that encompasses the majority of the components found on a web page [80]. Bootstrap offers numerous benefits, such as being open source, which makes it user-friendly for developers. It also provides extensive documentation, making problem-solving a breeze. Additionally, it is known for its speed and lightweight nature [73]. Although Laravel is a framework designed to facilitate web application development and help developers achieve their goals [81].

The integration of API, MySQL, Laravel, and bootstrap will create an agile support system for Internet of Things (IoT) applications. For layer farmers, integrating these four characteristics will enhance the usability and efficiency of web-based interface applications for data collection and analysis.

C. *Proposed System*

Following a comprehensive analysis of existing literature and a thorough field investigation, the subsequent task involves scrutinizing the architecture of the proposed system, as depicted in Fig. 2. Fig. 2 illustrates the splitting of the design module into two modules: the measurement module and the monitoring module. The measurement module includes an Arduino UNO microcontroller, a DHT-22 temperature and humidity sensor, a MQ-135 gas sensor, an ESP32 as a gateway node to connect hardware with software, and a 16×2 I2C LCD to display the sensor readings.

The three parameters of the cage environment sense observation will present the sense data on the LCD display as a representation of the observation point, while the sense monitoring data will be transmitted through the WIFI network installed in the cage. The data is transmitted by the ESP32 and received by the API and database server. Furthermore, the ESP32 CAM can be accessed by the farmer to visually monitor the cage on the monitoring dashboard.

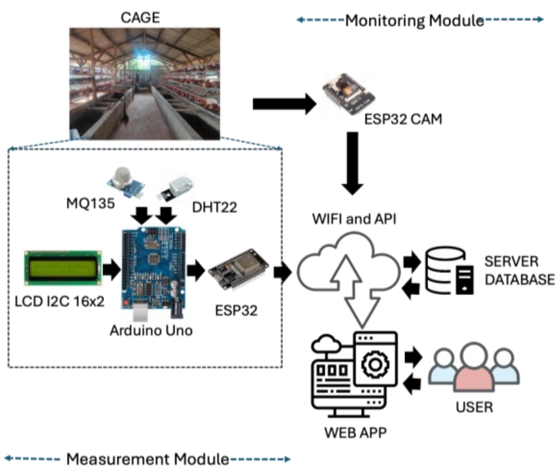

Fig. 2. Block diagram of proposed system

The monitoring module is constructed using the measurement and detection module, incorporating IoT technology through the integration of web and Android-based

APIs, databases, dashboard displays, and ESP32 CAM. These components are utilized simultaneously in both modules. In the measurement module, the results will present on the LCD display, whilst the data monitoring module will display them on the web application. Therefore, the system can display the measurement results in the cage and the system can be accessed wherever the farmer is located to monitor the cleanliness of the cage.

The principles of the proposed system are illustrated in Fig. 3. The flowchart in Fig. 3 illustrates the process of how the proposed system operates. When the device is turned on, the DHT-22 sensor and the MQ-135 sensor will start working to collect data that will be used to measure the temperature, humidity, and ammonia gas levels in the area around of the cage. After the sensor has been initialized, the MQ-135 sensor will begin the calibration process. Calibration is performed to verify that the sensor provides accurate and reliable measurements of the parameters being assessed. After the calibration process is finished, the MQ-135 sensor and DHT-22 sensor will begin measuring the temperature, humidity, and ammonia gas levels in the surrounding environment of the cage.

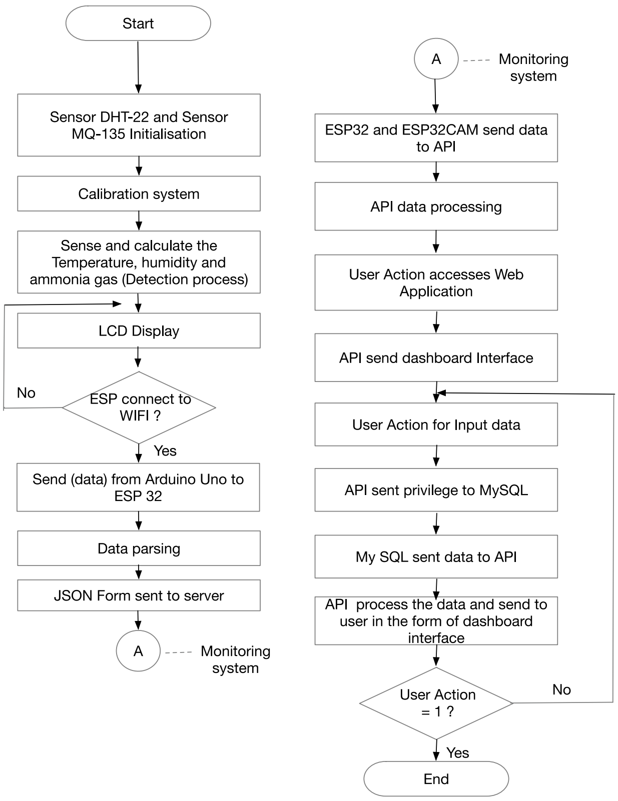

Fig. 3. Flowchart of proposed system

The LCD screen will display the values that have been retrieved. In addition, ESP2 will automatically connect to the Wi-Fi network. If it is not connected, it will establish a connection. After establishing a connection, the sensor data will be transmitted to the server in JSON format for processing and integration into the website monitoring system.

The flowchart will proceed in the monitoring system module. After the sensor has assessed the state of the laying hen cage, the data is sent to the ESP32 over serial communication. Subsequently, the ESP32 transmits the sensor reading data alongside the ESP32CAM's image data to the internet server using WIFI.

Furthermore, the data acquired from the ESP32 is transmitted to the API for analysis and systematically recorded in tables on the database server. The cage officer utilizes a web browser to access the web application. The web browser initiates a request to the web API, which then deliver data in the form of a dashboard display to the web page. After all tasks are completed, the user can easily terminate the web application. At this point, there has been a change in the color utilized to delineate parameters. The presence of parameters that exceed the allowable threshold is indicated by the red color, while the green color signifies that parameter measurements are still within the allowable range.

D. Prototype

Fig. 4 illustrates the configuration of the 3D modeling, which serves as a container or casing for the measuring system device. The case functions as a secure enclosure to protect and shield the system components from adverse effects. The 3D model of this device took into account various factors, including the dimensions and configuration of the components, the robustness and user-friendliness of the casing, and the accessibility of ports and buttons. Furthermore, the 3D case model takes into account aesthetic aspects to enhance the visual appeal of the detection system created.

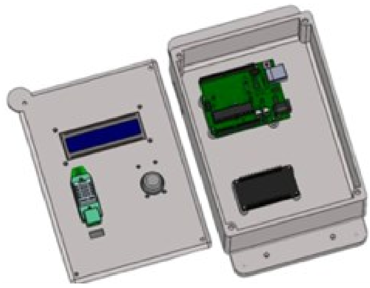
Fig. 4. 3D model container

Finally, the circuit is properly packed within a case fabricated utilizing state-of-the-art 3D printing technology. The prototype can be seen in Fig. 5, displaying an image of the circuit used in the detecting system for environmental conditions in laying hen cages. The prototype circuit of the detecting system is intended to optimize the process of creating the hardware circuit for the system. In addition, the prototype circuit plays a crucial role in carrying out testing experiments and verifying the functionality of the designed circuit in the following section.

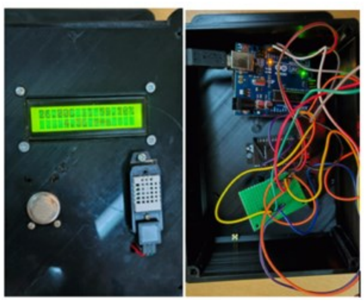
Fig. 5. Prototype

III. Result and Discussion

A. Implementation

After the prototype is finished, the subsequent step is to test the prototype in the actual environment of the laying hen cage. The environmental condition detection system for laying hen houses was evaluated by integrating three prototypes at different observation points. The prototype test was conducted in a layer cage located in Cilengkrang Village, Bandung, Indonesia. The design of this layer cage utilizes an open-house type cage model. There are about 400 laying hens that produce an average of 18 kg of eggs daily. Fig. 6 shows a description of the laying hen cage utilized as the implementation and testing site for the proposed system.

Fig. 6. Testing site at open-house type cage

Given the spacious nature of the layer hen cage, it is crucial to conduct comprehensive observations at various points and utilize various measuring instruments. Thus, the measurement module is divided into 9 measurement points with positions illustrated in Fig. 7. Therefore, the positioning of the prototype for data collection in the cage is also strategically planned in the same position.

Fig.7 illustrates the testing of each device in three different positions on the pole, represented by matrices and coordinates. Position 1, 2, 3 represent the vertical position, while positions A, B, and C represent the horizontal positions. Each pole in the cage is equipped with a node that includes an Arduino UNO microcontroller, DHT-22 temperature and humidity sensor, MQ-135 gas sensor, ESP32 microcontroller, and 16×2 I2C LCD. The default measurement positions are located on poles A2, B2, and pole C2. Every pole is positioned at the coordinate point (0, 2).

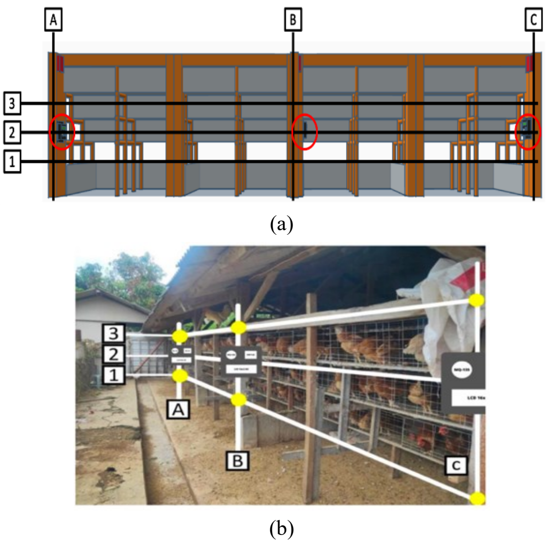

Fig. 7. Mapping the placement of measurement points

B. Experiments

Experiments were conducted to evaluate the efficacy of integrated sensors in detecting the environment of a chicken cage. These tests are performed at three specific coordinate points on the cage pole, specifically point A2, B2, and C2, as seen in Fig. 8. Testing at these three points is conducted to assess the level of dirtiness by analyzing the detection results. Considering the size of each room in the cage and considering the number of hens that can move freely in the cage, it can lead to different levels of dirtiness at each measurement point. measurement.

Fig. 8. Measurement points

According to certain literature, it is recommended to maintain a temperature range of 27°C-34°C and an air humidity level of 45%-65% for the cage area. Meanwhile, the ammonia level that is acceptable and does not cause distress in hens are typically less than 20 ppm [82], [83]. For this test, a threshold of 15 parts per million (ppm) is utilized. This was conducted to avoid any potential increases in odor concentration that could occur beyond the acceptable limit of extreme weather fluctuations. The experiment was carried out for seven full days, covering morning (08:00 am), afternoon (1:00 pm), evening (5:00 pm), and night (8:00 pm). The test results are displayed in the graph shown in Fig. 9.

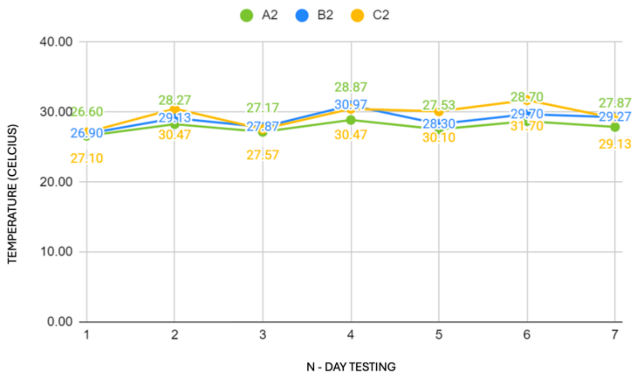

Fig. 9. Temperature testing result for 7 days experiment

Fig. 9 displays the test results at point A2 in green, point B2 in blue, and point C2 in orange. The data is collected as a time samples between 1 pm and 4 pm. The results indicate that the temperature can be used to assess the environmental conditions around the laying hen cage, as it is closely resembling room temperature. The variation in temperature arises from the large space of the room and the varying wind patterns. The test results in certain testing points experienced slight variations in warmth or coolness.

Fig. 10 illustrates the standard deviation in error between the system and a conventional digital thermometer, as the current instruments. The collected data represents the mean value of samples obtained on a daily basis within a 24-hour period.

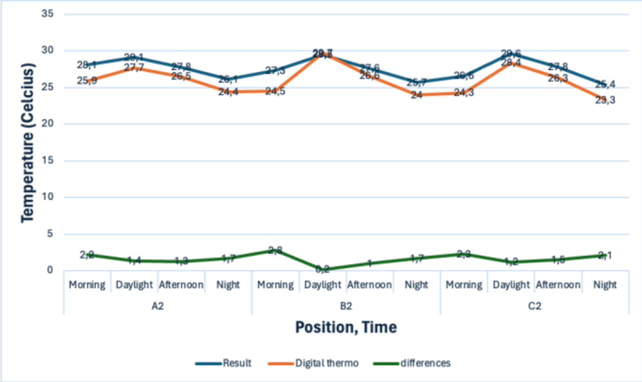

Fig. 10. Comparation temperature testing result in a day

In Fig. 10, the blue color represents the results of system testing, the orange color represents the results of thermometer measurements, and the green color represents the difference or discrepancy in measurements. According to this analysis, it can be seen that the test results show variations in the measurements obtained by the system, ranging from 0.5^0C to 2.8^0C, when compared to the digital thermometer test results.

Therefore, it can be concluded that the temperature sensor test did not produce significant differences. Of the many tests conducted, errors of up to 2.80 only occurred twice. The variation in inaccuracy can be related to the discrepancy in heat generated by the prototype during detection. Subsequently, examine the humidity levels measurement around the laying hen cage using a similar approach to the temperature test as previously discussed. The measurement will be compared with hygrometer as an existing tool. Fig. 11 displays the result of the humidity test.

Testing the humidity levels over a span of 7 days has provided highly accurate results. The humidity value around the laying hen cage was measured at 39.10%, with the highest recorded humidity value reaching 68.40% The elevated humidity levels are a consequence of the layer house and the slightly cloudy weather, causing an increased concentration of water vapor in the atmosphere. The data that displaying in Fig. 11, is the data of the humidity measurement results as similar period to the previous experiment. The data was collected as a sample during the time frame of 1 pm to 4 pm. The data collected during the specified time period indicates that the humidity level ranges from 45.43% to 60.77%.

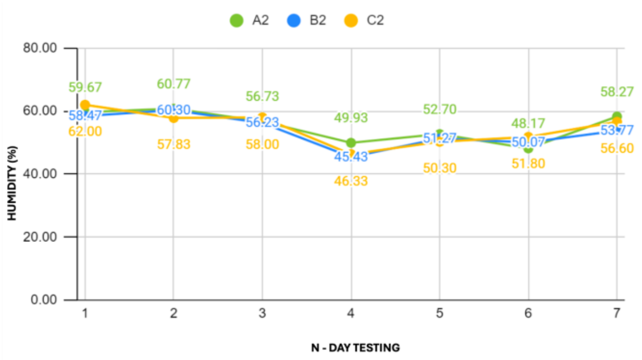

Fig. 11. Comparation testing result in a day

In addition, Fig. 12 illustrates the difference value obtained from the humidity measurement with a hygrometer as the existing tools.

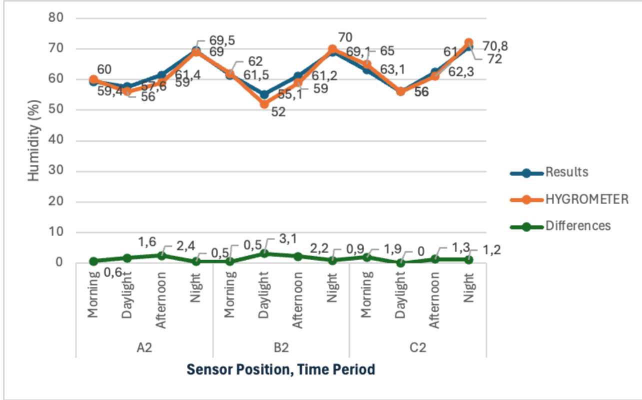

Fig. 12. Comparation humidity testing result in a day

The Fig. 12 shows that the variation in measurement results is within the range of 0.5% to 3.1%. The results of testing the humidity value for 7 consecutive days show a remarkable level of accuracy when compared to the measurement results obtained from the hygrometer. The results of measurement of the humidity of the laying hen cage stated that the environmental conditions of the laying hen cage are still in the normal range of the threshold in the range of 45% - 65%. Occasionally there are dry conditions of the hens' cage environment (39%). This is due to the dry condition of the hen cage due to weather factors at the time of taking the test.

Meanwhile, the findings of the ammonia gas test are depicted in the Fig. 13. The test results for 7 consecutive days show the levels of ammonia gas in the laying hen cage environment, as measured by the MQ-135 sensor, based on the condition of the dirt in the cage. The process of measuring ammonia gas levels in the laying hen cage environment involves calibrating against clean air using a specific formula (1) [84].

$$Ammonia\ gas\ levels = \frac{RS}{RO\_Clean\_air} \quad (1)$$

The parameter RS indicates the resistance value of the sensor while RO_Clean_air is the resistance value of clean air outside the cage.

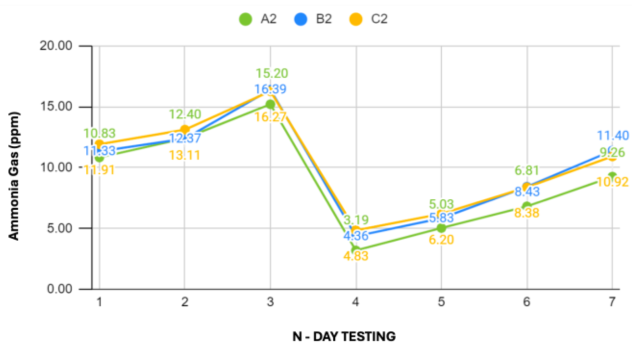

Fig. 13. Ammonia Gas testing result for 7 days experiment

The highest ammonia gas concentration occurred on day 3, just one day prior to the cage cleaning conducted by the laying hen farmers. The ammonia levels recorded at poles A2, B2, and C2 were 15.20 ppm, 16.39 ppm, and 16.27 ppm respectively, with an average concentration of 15.95 ppm. All the ammonia gas values measured on day 3 exceed the predetermined threshold limit of 15 ppm, necessitating immediate cage cleaning. During this period, testing was also conducted at the closest point to the dirt, using three poles to obtain an average result of 14.24 ppm.

After the cage were cleaned, the test results on the day 4 showed a decrease in the ammonia gas levels in the hen cage environment. The values recorded on pole A2, pole B2, and pole C2 are 3.19 ppm, 4.36 ppm, and 4.83 ppm, respectively. It has an average value of 9.74 ppm over a span of 7 days. There is no comparison between the proposed system and the existing system, as the former system did not utilize a sensor to detect the presence of gas in the vicinity of the cage area. However, the graph depicts the concentration level of ammonia gas in the air, enabling laying hen farmers to efficiently verify the cleanliness of their cages.

Furthermore, in Fig. 14 depicts the information displayed on the LCD screen regarding the testing of the three parameters: temperature, humidity, and ammonia gas levels. Each prototype located at coordinate positions A2, B2, and C2. Variations in the measurements of the three parameters at the three locations could be due to the volume of chicken dirt, the varying humidity levels of the dirt at each measurement point, and the airflow pattern entering the cage as a result of the open-house design. However, these performances can assist laying hen farmers in identifying the specific location within the cage that is the dirtiest and require immediate cleaning. The overall display effectively presents the measurement results.

Fig. 14. LCD display of 3-parameter measurement results

After the measurement module has been extensively tested, it is time to testing the monitoring module. Fig. 15 displays the results of evaluating the monitoring interface data on the web. Testing is conducted by accessing the web application address. The web page utilizes the Indonesian language for its display.

Fig. 15. Monitoring module performance

Fig. 16 shows a dynamic presentation of the laying hen cage measurement device. This page presents three parameters: temperature, humidity, and gas values. Additionally, there is a video monitor that shows the current state of the laying hen house. In the monitoring system, threshold information is expressed through the use of color-coded rules. Green color signifies measurement results that fall within the allowed threshold, while red color indicates measurement results that exceed the permissible threshold.

(a) (b)

Fig. 16. Monitoring module result: (a) unsafe state; (b) permissible state

Fig. 16 (a) illustrates that a parameter, specifically temperature, exceeds the alowable range at 30.7^{0}C. Consequently, the monitoring display indicates a red warning, which signifies an unsafe environment for laying hens. Therefore, applying color-coding rules to the display will increase the convenience and awareness of layer hen farmers when interpreting the measurement results within the cage. Meanwhile, in Fig. 16 (b), the monitoring display depicts the usual condition of the laying hen house. All measurement results are within the permissible threshold, as indicated by the green display indicator.

The final test involved evaluating the data recording view for all the information stored in the system. This page is available for laying hen farmers to conveniently view a summary of all measurement results stored in the system. Fig. 17 displays the dashboard of the data recording table. In this dashboard, laying hen farmers have the option to select and perform actions based on the position of the sensor points they wish to read by day or by date. The test results indicate that the recorded data can be conveniently displayed and accessed through search queries, enabling the laying hen farmers to monitor the cages from any location.

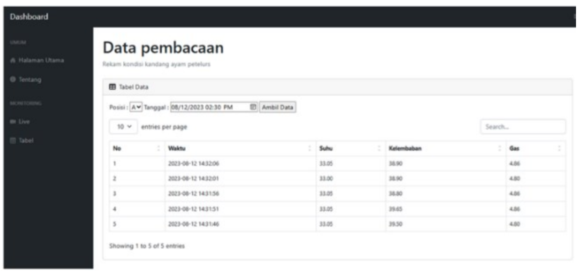

Fig. 17. Reading page performance

According to the test findings of the measuring module and the monitoring module, it can be concluded that the proposed system offers substantial improvements compared to the previous system. By including additional features such as the MQ135 sniffing sensor, streaming webcam, and monitoring dashboard, this system may efficiently and precisely provide laying hen farmers with real-time information regarding the cleanliness of the cage environment. This will indirectly lead to increased alerts for laying hen farmers regarding healthy laying hen productivity improvement and management practices.

In addition, this proposed system can also be used in a large space areas of laying hen farmers. The laying hen farmers can remotely monitor the cage by increasing the number of sensing points and accessing the information dashboard for those sites. The limitation of this system is its reliance on WIFI connectivity and its power consumption while connected to the system.

IV. CONCLUSIONS

This research has developed a system that can assist laying hen farmers in effectively managing and improving the health of their laying hens. This system excels in providing real-time and precise information. This instrument is highly effective at accurately detecting temperature, humidity, and ammonia gas levels conditions in the laying hen cage environment. It provides measurements with a precision of 0.5^0 C to 3^0 C from the previous device. In addition, the accuracy of ammonia gas levels measurement is improved because the sensor is calibrated against the resistance value of clean air. The laying hen cage is equipped with a 16×2 LCD screen and a monitoring system web application. This allows the laying hen farmers to easily view the value of each parameter, regardless of their location. Furthermore, all measurements are meticulously stored on the server, allowing the laying hen farmers to analyze the historical data whenever necessary. Historical data can be utilized for data analysis if there are any exceptional events, such as a significant decrease in laying hens health or a notable drop in egg production rates. By ensuring a meticulous level of cage hygiene, it is expected that the overall environmental cleanliness of laying hens will improve, as laying hen farmers become more aware of the cleanliness of their cages. Physiologically, this will help ensure the health of the laying hens and increase egg production compared to traditional methods.

In order to enhance the efficiency of future works, an automatic conveyor belt can be incorporated next to the floor for mechanized cleaning. The automatic conveyor belt system efficiently collects chicken dirt from the floor, concentrating it in one location for cleaning. This integration would enable the system to seamlessly detect and clean the cages of laying hens as part of a smart system. Furthermore, the inclusion of a camera with enhanced resolution would allow farmers to effectively monitor the condition of their laying hen cages from multiple perspectives using computer vision to detect the chicken manure. To enhance the productivity of laying hens, an additional feature can be incorporated into the existing system, which immediately computes the daily egg production. In the future, it might be further enhanced to create a detecting device capable of measuring the size and weight of individual eggs, enabling the assessment of the quality of eggs produced by each laying hen.

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