A Novel Integrated System for Greenhouse Gas Reductionin Poultry Farms

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ABSTRACT: The poultry industry is one of the largest and fastest-growing agro-based industries in the world and its production is increasing globally. However, a major problem faced by the poultry industry is the large-scale accumulation of wastes including manure and litter which may cause pollution problems to the environment. Poultry litter is a significant source of greenhouse gas emissions, emitting carbon dioxide, ammonia, and hydrogen sulphide.This study investigates the management of ammonia (NH_3) emissions in poultry farming by the use of biofilter medium and sensor technology. In addition, a biofilter media may efficiently absorbs NH_3 and volatile organic compounds and improves air quality. To ensure optimal performance and real-time monitoring, the system is equipped with sensors, including an ammonium sensor and gas detectors. These sensors continuously measure the levels of various greenhouse gases (GHGs), temperature, and humidity in the poultry farm. The data collected by the sensors is then processed by an ESP 32 microcontroller and used to dynamically adjust the system's operation, such as airflow through the ventilation system for the reduction of greenhouse gases. This integrated approach offers a sustainable and efficient solution for greenhouse gas reduction. By combining the adsorptive properties of Vetiveria zizanioides with the biological activity of biofilters and the intelligent control of sensor technology, the system has the potential to significantly minimize the environmental impact of poultry farming while maintaining animal welfare and production efficiency.

Keywords: Poultry litter, greenhouse gas, Vetiveria zizanioides, sensors, Microcontroller

I. INTRODUCTION

[1].Over the past 20 years, the poultry business has advanced significantly, made possible by ongoing efforts in a number of areas, such as farms, hatcheries, processing facilities, and nutrition

[2].Sustainable poultry farming practices have become imperative, not only for mitigating environmental impacts but also for ensuring the welfare of the birds and the livelihoods of the poultry farmers who depend on this poultry industry

[3]. It provides a stable protein supply as well as food and nutritional security for a wide range of populations in rural areas around the world, especially in developing countries. While poultry production is one of the most efficient forms of livestock management with regards to natural resource use and protein gain, it can still have a significant impact on human health and the environment. Intensive broiler farming produces emissions that affect several aspects of the environment, including air, water, and soil

[4]. Therefore, it is important to maintain optimal conditions for poultry production and also it should not impair the human and animal environment through emission of harmful gases. The high stocking density in modern poultry barns may contribute to decreased air quality, with significant concentrations of organic and inorganic dust, pathogens and other microorganisms, as well as hazardous gasses such as ammonia, nitrous oxide, carbon dioxide, hydrogen sulfide, and methane

[5].Ammonia is produced in broiler facilities by the biological breakdown of uric acid, which occurs within a few days.

[6].Increased NH_3 concentrations in poultry barns lower feed intake, slow down the rate of bird growth, reduce egg production, harm the respiratory system, rendering birds more susceptible to Newcastle disease virus, raise the risk of kerato conjunctivitis and air sacculitis, and increase the prevalence of Mycoplasma gallisepticum

[7].Poultry farms contribute as a major environmental pollutant by releasing Ammonia, Hydrogen Sulphide, Carbon dioxide, Methane, and volatile organic compounds

[8]Ammonia and hydrogen sulphide emissions from poultry waste pose health risks to birds, farm workers, and nearby communities. High concentrations of these gases can lead to respiratory problems, reduced feed intake, and increased disease susceptibility in poultry

[7] . The breakdown of animal urine and manure is the primary contributor of ammonia emissions, which may lead to solid acidification and air pollution

[9].The main source of hydrogen sulphide emissions is the anaerobic breakdown of organic matter contained in manure, which can cause unpleasant odor and respiratory irritations

[10].Zeolite, a naturally occurring mineral, has been shown to be highly effective in adsorbing and neutralizing NH3 emissions, due to its high surface area and cation exchange capacity

[11].The use of zeolite and lime powder as neutralizing agents for NH3 emissions has been increasingly popular in recent years, due to their low cost, ease of use, and environmental sustainability

[12].Addition of zeolite may provide numerous benefits during the composting, because porous micro-structure of zeolite leads to reduce the emission of mixture of gases and act as biofilter

[13].Bofilter media, such as activated carbon, wood chips, and coconut husk, have been widely used for gas absorption and pollution control in various industries, including poultry farming

[14].These media activated carbon, vetiveria zizanioides, and coconut husk, can effectively remove ammonia, hydrogen sulphide, and VOCs from the air. These media improve indoor air quality and reduce the environmental impact of poultry farms

[15].The use of biofilter media for gas absorption has been increasingly popular in recent years, due to their low cost, ease of use, and environmental sustainability

[8]IoT technologies are integrated into an intelligent poultry management system to monitor and regulate a number of farm factors, including GHG levels like hydrogen sulfide (H2S) and ammonia (NH3). The system utilizes sensors such as ammonia, temperature and humidity sensors, and H2S gas detectors to continually monitor GHG levels and other environmental parameters including temperature and humidity. The system initiates corrective measures that mitigate the issue when NH3 levels above predetermined criteria. These actions may include activating ventilation systems to reduce the concentration of NH3 in the air. By addressing NH3 levels promptly, the system helps minimize odor and fly infestation, creating a healthier environment for the poultry
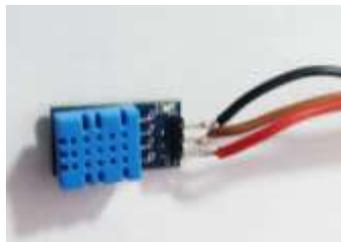
II.MATERAIALS

Figure 1 MQ2 sensor

Figure 2 MQ3 sensor

Figure 3DHT 11 Sensor

Figure 4 Relay controller

Figure 5 LCD display
(16X2)

Figure 6 Micro controller

2.1 VENTILATION SYSTEM
INLET AND OUTLET FAN
[16]. Effective ventilation is critical in poultry farming, as it has a direct impact on bird health, productivity, and overall facility environmental conditions. To ensure an efficient air exchange, the system relies on a careful balance of intake and output fans. Inlet fans, which are often installed to draw fresh air into the barn, are critical for ensuring a steady supply of oxygen and diluting hazardous gasses such as ammonia and carbon dioxide. These fans help to create a positive or negative pressure differential, depending on the system design, which drives airflow. Inlet fans must be properly positioned and sized to ensure regular air spread and minimize inactive regions, which can lead to variation in temperature and increased illness risk

PREFILTER
[17].Prefilters play a crucial role in maintaining air quality within poultry farms by capturing large dust particles, feathers, and other airborne contaminants before they reach the main filtration system. These filters enhance the efficiency and lifespan of high-efficiency particulate air (HEPA) or electrostatic filters, reducing the risk of respiratory diseases among poultry and improving overall farm hygiene that effective prefiltration minimizes ammonia levels, airborne pathogens, and particulate matter,

contributing to better bird health and productivity

CARBON FILTER
[18].Activated carbon filters are widely used in poultry farms to control ammonia, volatile organic compounds (VOCs), and odor emissions, thereby improving air quality and bird health. These filters work by adsorbing harmful gases and airborne contaminants, reducing respiratory issues among poultry and farm workers. Additionally, carbon filters contribute to biosecurity by minimizing the spread of airborne pathogens, making them an essential component of modern poultry ventilation systems. Integrating carbon filtration into exhaust and recirculation systems enhances overall environmental management, leading to better farm productivity and sustainability

BIOFILTER
[19].Biofilters represent a promising technology for mitigating air pollutants emitted from poultry farms, addressing growing concerns about environmental impact and animal welfare. These systems utilize microorganisms immobilized on a solid support matrix to degrade volatile organic compounds (VOCs), ammonia, and other odorous compounds released from poultry manure and litter. The effectiveness of a biofilter is contingent on factors such as the type of filter

media, airflow rate, temperature, humidity, and the microbial community's composition Biofilters represent a promising technology for mitigating air pollutants emitted from poultry farms, addressing growing concerns about environmental impact and animal welfare.

[20].Biofiltration systems incorporating zeolite and vetiver offer an effective approach to mitigating air and water pollution in poultry farms. Zeolite, a porous aluminosilicate mineral, is known for its high cation exchange capacity and adsorption properties, making it efficient in capturing ammonia (NH_3) and other odorous compounds from poultry waste.

2.2 IOT SYSTEM
TEMPERATURE SENSOR

[21].Temperature sensors are critical in poultry farming for maintaining optimal environmental conditions that support bird health, growth, and productivity. These sensors continuously monitor temperature levels within poultry houses, enabling automated climate control systems to adjust ventilation, heating, and cooling mechanisms accordingly. Advanced temperature sensors integrated with IoT-based monitoring systems enhance precision farming by providing real-time data, improving energy efficiency, and ensuring animal welfare. Implementing sensor-based climate control reduces mortality rates and promotes sustainable poultry production

[22].These sensors continuously monitor relative humidity (RH) levels in poultry houses, allowing automated climate control systems to adjust ventilation and heating to avoid excess moisture accumulation. High humidity, particularly above 70%, may increase ammonia deposition from litter decomposition, resulting in respiratory problems and increased illness susceptibility in birds, low humidity can cause dehydration and poor feather condition. The DHT11 temperature and humidity sensor comes both in sensor and module form. The pull-up resistor and a power-on LED distinguishes this sensor from the module. DHT11 is a relative humidity sensor. This sensor makes use of a capacitive humidity sensor and a thermistor to measure the ambient air. A thermistor for temperature detection and a capacitive humidity detecting element make up the DHT11 sensor. With a 2-degree precision, the DHT11's temperature range is 0 to 50 degrees Celsius. Humidity range of this sensor is from 20 to 80% with 5% accuracy.

[23].Integrating humidity sensors with real-time monitoring and IoT-based control systems improves air quality, litter management, and energy efficiency, ultimately enhancing overall poultry farm sustainability.

AMMONIUM AND HYDROGEN SULPHIDE GAS SENSORS

[24].Ammonia sensors are essential in poultry farming for monitoring and controlling ammonia (NH_3) concentrations, which can negatively impact bird health, productivity. Ammonia is primarily generated from the breakdown of uric acid in poultry litter, and excessive levels (above 25 ppm) can cause respiratory distress, eye irritation, and reduced growth rates in birds. Advanced ammonia sensors enable real-time detection and integration with ventilation systems to maintain NH_3 levels within safe limits. Research has shown that continuous ammonia monitoring improves air quality, enhances immune function in birds, and reduces disease outbreaks. Implementing sensor-based ammonia management strategies contributes to better farm sustainability and overall animal welfare.

[25].Hydrogen sulfide (H_2S) is a hazardous gas commonly produced in poultry farms due to the decomposition of manure and organic waste.

[26].Exposure to high concentrations of H_2S can pose serious health risks to poultry workers and birds, leading to respiratory issues, decreased productivity, and even fatalities in extreme cases.

[27].To mitigate these risks, hydrogen sulfide gas detectors are installed in poultry houses to provide real-time monitoring and early warning systems (Garcia et al., 2022).

[28]. These detectors are often integrated with ventilation systems to automatically activate fans or air purification mechanisms, ensuring a safer environment (Williams et al., 2021).

[29].Additionally, regular calibration and maintenance of H_2S and ammonia gas detectors are essential to ensure accuracy and reliability in detecting hazardous gas levels (Zhang & Wu, 2020).

[30].Here we are using MQ2 and MQ5 gas sensors for effective monitoring of greenhouse gases in poultry farms(Praveena et al. 2024)&(Tech 2024).

CONTROLLER RELAY

[31].A controller relay is an essential component in modern poultry farming, enabling automated control of various environmental parameters such as temperature, humidity, ventilation, and lighting. These relays act as intermediaries between sensors, controllers, and farm equipment, ensuring operation by switching devices on or off based on programmed conditions. In a poultry house, temperature sensors may trigger a relay to activate cooling fans or heaters to maintain optimal conditions for bird growth and health. Advanced programmable logic controllers (PLCs) and IoT-based relays enhance precision by allowing remote monitoring and control, reducing labor costs and improving productivity. Studies have shown that automated relay-based systems contribute to better poultry welfare, higher feed conversion ratios, and reduced mortality rates (Ramesh et al., 2021).

[32].The integration of smart relays with cloud-based platforms further optimizes farm operations by providing real-time data analytics and predictive maintenance (Singh & Kumar, 2022).

LCD DISPLAY

[33].The integration of Liquid Crystal Display (LCD) technology in poultry farming has significantly enhanced monitoring and automation systems (Smith et al., 2021).

[33].L C screens are used to display real-time data related to environmental conditions such as temperature, humidity, and air quality within poultry houses (Johnson & Lee, 2020).

[34].These displays provide farmers with immediate access to critical information, improving efficiency and reducing manual workload (Brown et al., 2019).

[35].Modern poultry farms incorporate LCD screens with microcontroller-based systems to control ventilation, lighting, and feeding mechanisms (Williams & Thompson, 2022).

[36].Such systems enable precision farming, ensuring optimal bird health and productivity (Garcia et al., 2021).

Furthermore,LCD displays integrated with IoT-based sensors allow remote monitoring through wireless communication.

ESP32 MICROCONTROLLER

[37].The ESP32 microcontroller is a cost-effective, power-efficient, and highly versatile IoT-enabled device that is increasingly being utilized in smart poultry farming. Its dual-core processor, integrated Wi-Fi, Bluetooth capabilities, and extensive GPIOs make it suitable for automating environmental monitoring, feeding systems, and security applications in poultry farms (Bhatia & Sharma, 2021).

[38].The ESP32 is interfaced with DHT11, MQ2, and MQ5 sensors to monitor environmental conditions and ensure the well-being of poultry.The DHT11 sensor measures temperature and humidity, crucial factors in poultry farming, as improper climate conditions can affect bird health and productivity.The MQ2 and MQ5 gas sensors detect hazardous gases such as ammonia, methane, and carbon monoxide, which can accumulate in enclosed poultry spaces due to decomposing waste and inadequate ventilation (Ali et al., 2021).

High levels of these gases can lead to respiratory issues and increased mortality rates in poultry (Singh et al., 2019)**.**


Figure 7 Working model

III.EXPERIMENTATION

[39].This experiment was carried out in March 2025. A broiler poultry farm was selected for field data collection based on noticeable levels of ammonia emissions, making it an ideal environment to observe real-time gas concentration patterns. A representative area within the broiler house was chosen for installing the IoT-based environmental monitoring system. The system, equipped with sensors for ammonia, temperature, and humidity detection was installed in passive mode without connecting to any ventilation or control systems. Environmental data of the selected poultry house was collected continuously for five days, with sensor readings automatically uploaded to a cloud platform for storage and analysis. This on-site monitoring phase aimed to capture natural fluctuations in environmental conditions and evaluate the system's ability to operate reliably in a farm setting. Following the field deployment, poultry litter samples were

collected from the monitored broiler house area. At the moment of litter sample collection, the hens were 8 weeks old and were fed by industrial feed mixtures (cereal grains, cereal by products). After collection, the litter samples were moved to the site of the experiment in which environmental temperature and humidity were monitored.

[40].Laboratory testing was conducted over another five-day period to specifically assess the performance and accuracy of the IoT system in a controlled environment. The experimental setup consisted of a sealed chamber containing dried poultry litter, designed to simulate a poultry house environment. A custom-built ventilation system was integrated, featuring an inlet and outlet fan, a prefilter to remove dust particles, an automotive-grade carbon filter for VOC removal, and a bio filter chamber housing perennial grass (Vetiveria zizanioides) and zeolite. Vetiver's dense root system can filter particulate matter, which can indirectly improve air quality. Improving overall air quality can contribute to a healthier environment, which can indirectly influence gas emissions.

An IoT system was implemented to monitor and control the ventilation, comprising humidity and temperature sensors, ammonia (NH3) and hydrogen sulfide (H_2S) gas detectors, a controller relay, an LCD display, and a power supply unit. Sensors were strategically placed within the chamber to provide representative data, and the ESP32 microcontroller was programmed to log sensor readings at predetermined intervals, calculate an Air Quality Index (AQI), and the relay automatically activate the fans when sensor thresholds were exceeded. This is achieved manually as well as automatically. Data acquisition involved continuous logging of temperature, humidity, NH3, and H2S levels, were stored by Things peak and Blynk platforms. System optimization was achieved through fine-tuning sensor thresholds and experimenting with different ratios of wood chips to zeolite in the bio filter. This two-stage approach real-world observation followed by controlled laboratory testing allowed for both the collection of practical environmental data and the validation of the IoT system's consistency, sensitivity, and reliability in detecting ammonia and related parameters under different conditions. .
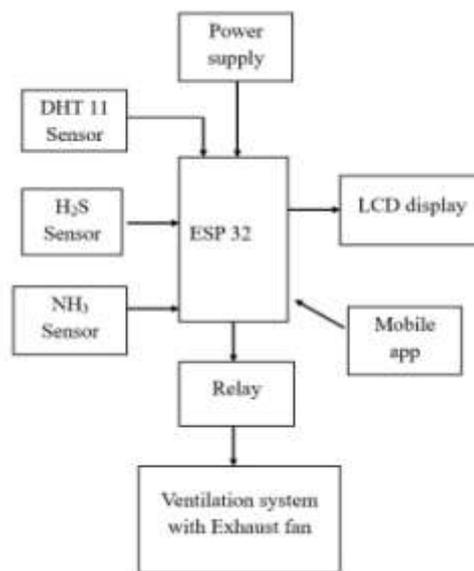
LINE DIAGRAM FOR INTEGRATED SYSTEM FORGREENHOUSEGASREDUCTIONIN POULTRY FARMS

IV. OBSERVATIONS THROUGH SYSTEM INTEGRATION IN POULTRY FARMS

The "Smart Poultry: A Novel integrated system for greenhouse gas reduction in poultry farms" was successfully developed and tested, demonstrating its effectiveness in optimizing environmental conditions in poultry farming through IoT-based automation. The system, combining IoT-based automation and a multi-stage ventilation system, demonstrated a significant reduction in greenhouse gases within the poultry farm environment. The ESP32 microcontroller, coupled with DHT11, MQ2, and MQ5 sensors, effectively monitored temperature, humidity, ammonia, and hydrogen sulphide levels in real-time. The collected data, visualized through Thing Speak and Blynk platforms, provided a clear and accessible overview of environmental conditions, allowing for remote monitoring and control via mobile devices. Notably, the ventilation system, comprising inlet/outlet fans, pre-filter, carbon filter, and a bio filter utilizing Vetiveria zizanioides, showed a marked decrease in measured gas concentrations. Specifically, the system effectively mitigated ammonia and hydrogen sulphide levels, crucial for improving air quality and reducing the environmental impact of poultry farming. The bio

filter, incorporating Vetiveria zizanioides, likely contributed significantly to this reduction due to its known capacity for absorbing and metabolizing volatile organic compounds and other pollutants. The real-time data logging and visualization capabilities facilitated by the IoT integration enabled precise monitoring of the system's performance and allowed for adjustments to optimize gas reduction. This integration of IoT and bio filtration represents a promising approach to addressing greenhouse gas emissions in poultry farming, offering a sustainable and efficient solution for improving air quality and animal welfare. The successful deployment of this system underscores the potential for integrating advanced technologies to create environmentally responsible agricultural practices. Further studies could explore the long-term efficacy of the bio filter, optimize the system's parameters for different poultry farm sizes and conditions, and evaluate the economic feasibility of implementing such integrated systems on a larger scale.

Table 4.1 Field Test Results from Broiler Poultry Farm Using IoT-Based Monitoring System

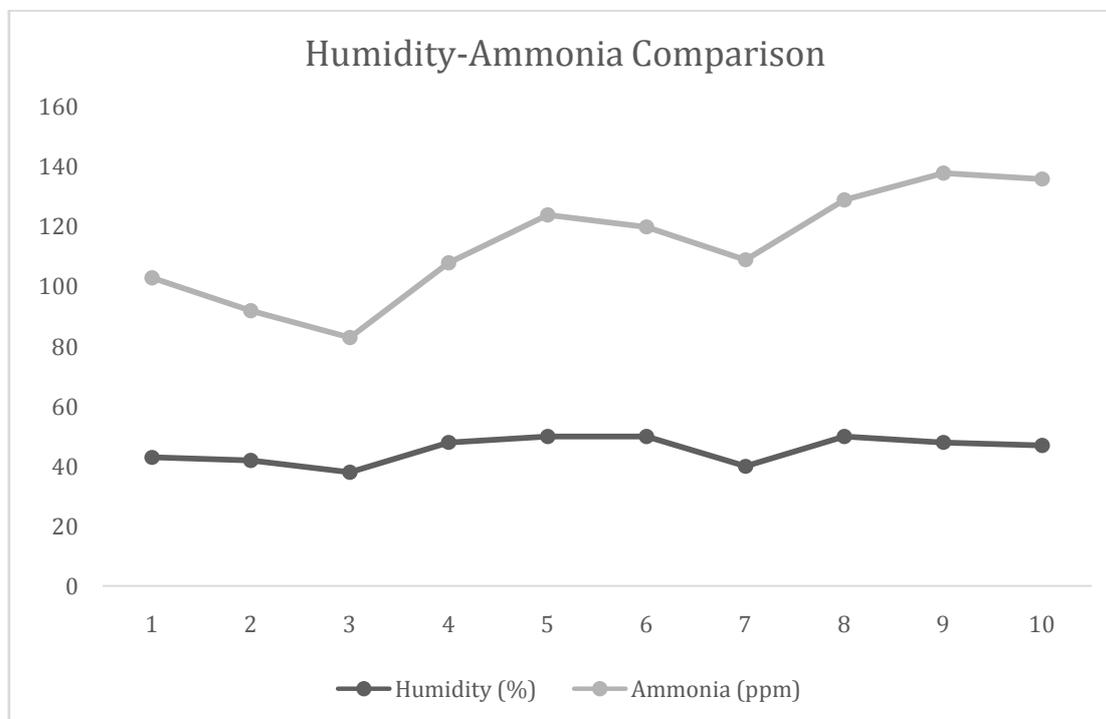| DAY	TIME	HUMIDITY (%)	TEMPERATURE (℃)	AMMONIA (ppm)
1	12pm-3pm	43	32	60
1	3am -6am	42	25	50
2	12pm -3pm	38	31	45
2	3am-6am	48	26	60
3	12pm-3pm	50	29	74
3	3am-6am	50	30	70
4	12pm-3pm	40	29	69
4	3am-6am	50	30	79
5	12pm-3pm	48	31	90
5	3am-6am	47	28	89

Figure 4.1Trend Comparison of Humidity and Ammonia Levels During Field Testing (Without ventilation System)

Field Testing of IoT- system in Poultry Farm

The IoT-based environmental monitoring system was first tested independently to evaluate its ability to accurately sense and record humidity, temperature, and ammonia concentration. The system was deployed for five consecutive days in a broiler poultry environment, with data collected twice daily—once during peak afternoon hours (12 PM–3 PM) and once in the early morning (3 AM–6 AM). Table 4.1 summarizes the collected data.

The recorded values show that ammonia levels varied significantly over the day, ranging from 45 to 90 ppm. It was observed that ammonia concentrations tended to increase alongside humidity levels, particularly during early morning readings. For instance, on Day 3 and Day 4, the humidity was measured at 50% during the early morning period, with corresponding ammonia levels of 70 and 79 ppm, respectively. Similarly, on Day 5, with humidity at 47% in the morning, ammonia peaked at 89 ppm. These findings are consistent with existing literature, such as the study by Al-Ali et al. (2023), which reported a positive correlation between elevated humidity and increased ammonia volatilization in poultry environments. Higher humidity slows litter drying, thus promoting microbial activity and ammonia release

Table 4.2: Environmental Conditions and Ammonia Levels During Lab Test

| Test no	Temperature (℃)	Humidity (%)	Ammonia (ppm)	Remarks
1	30	28	33	Low temp, low humidity - ammonia well within safe range
2	32	35	36	Balanced temp/humidity - ammonia stable
3	33	42	39	Humidity increased slightly - ammonia controlled
4	31	38	34	Moderate environment - ammonia within ideal range
5	34	48	45	Higher humidity for ventilation support -ammonia safe
6	35	46	44	Warm, moist air - ammonia suppressed by litter control
7	36	41	46	High temp — ammonia held within limit by system
8	32	39	38	Well-ventilated — controlled ammonia emission
9	30	34	35	Clean litter + airflow maintained low ammonia
10	31	44	40	Slight humidity rise due to litter — ammonia remains safe
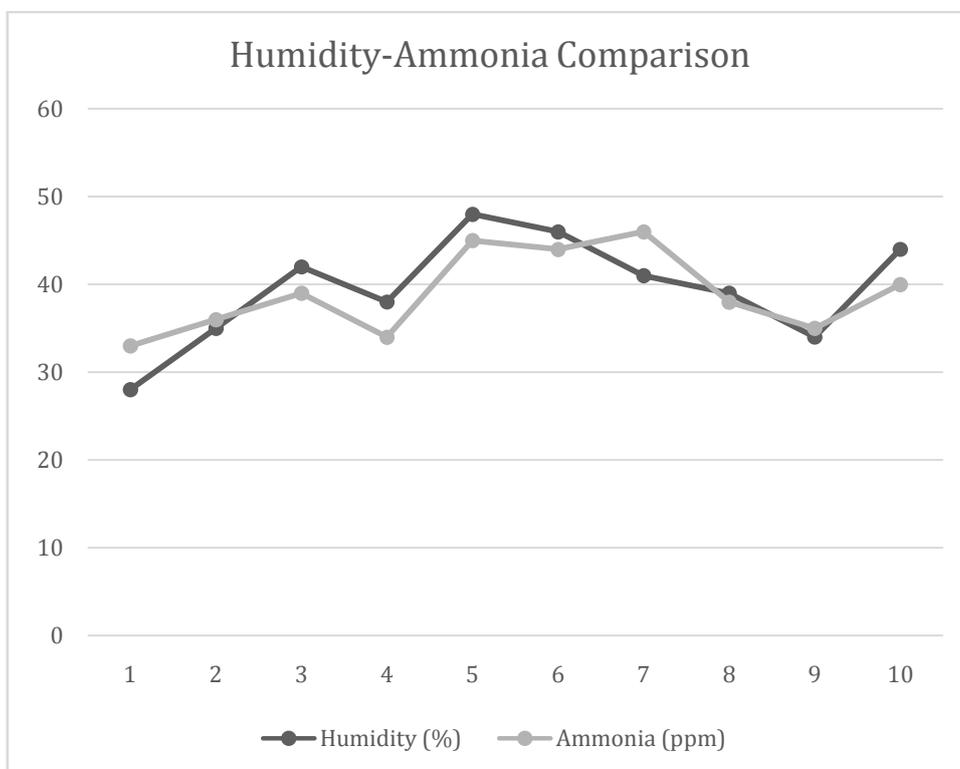
Figure 4.2: Comparison of Humidity and Ammonia Levels During Initial Test Conditions in laboratory

Laboratory Evaluation of Poultry Litter

To validate the effectiveness of the integrated emission control system, poultry litter collected from a broiler farm was subjected to laboratory testing under controlled conditions. The system included IoT-based environmental monitoring sensors, a mechanical ventilation setup, a Vetiveria zizanioides biofilter, and a carbon-zeolite filter. This test was performed without live poultry to focus

the system's efficiency in managing emissions even under

conditions that typically promote ammonia release.

The results show that the system effectively mitigated ammonia buildup through timely ventilation and filtration. For instance, the use of Vetiveria as a natural biofilter, combined with the adsorption capacity of carbon and zeolite, significantly reduced ammonia concentrations despite variations in environmental conditions.

These findings confirm that the integrated IoT-controlled emission reduction system functions efficiently in maintaining air quality and can serve as a practical solution for poultry farms aiming to control harmful gas emissions from litter buildup.

solely on the environmental impact and system performance.

As shown in Table 4.1, across ten test runs, the environmental parameters such as temperature ranged from 30°C to 36°C, and humidity from 28% to 48%. Ammonia concentrations remained within a safe and stable range, varying from 33 ppm to 46 ppm throughout all tests. Notably, in Test 5, even with high humidity at 48%, the ammonia level was controlled at 45 ppm. This indicates

V. CONCLUSION

This project successfully demonstrates the development and implementation of an ammonia reduction system for poultry environments, tested under controlled laboratory conditions. The primary objective was to reduce ammonia (NH_3) levels using a combination of biofilter media and sensor-integrated automation, and the results clearly indicate that the system worked effectively.The biofilter, composed of Vetiveria zizanioides, played a vital role in absorbing ammonia and other volatile compounds. Meanwhile, the system's real-time monitoring capabilities—enabled by gas sensors, temperature and humidity detectors, and an ESP32 microcontroller—allowed dynamic adjustment of environmental factors such as airflow and ventilation. These adaptive responses helped to maintain favorable conditions and minimize ammonia

buildup.Throughout a series of laboratory tests, a consistent pattern emerged showing that the ammonia levels were significantly reduced after the system was activated. This reduction was especially notable in comparison to initial readings, demonstrating the capability of the system to stabilize the environment effectively. The sensors not only captured fluctuations in gas concentrations but also provided accurate feedback to the controller to ensure precise and timely interventions.In conclusion, the laboratory results confirm that our system functions reliably in reducing ammonia emissions. This integrated approach offers a sustainable and intelligent solution for air quality management in poultry farming. The success of the system in a controlled setup provides a strong foundation for future deployment in actual poultry farms, where it can help reduce environmental impact while promoting healthier conditions for livestock.

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