SMART WASTE MANAGEMENT IN POULTRY FARMS: MONITORING AND CONTROLLING AMMONIA AND FLY INFESTATIONS

Jade Emmanuel A. Dela Peña
Guia Jazle L. Orzo
Ada Betina B. Villegas

College of Engineering
First Asia Institute of Technology and Humanities, Tanauan City, Batangas, Philippines
jade14dp@gmail.com, guiajazle@gmail.com, adabetinabville@gmail.com

ABSTRACT

The poultry industry has long held a significant position within the agricultural sector of the Philippines, playing a crucial role in contributing to the country's economy and overall food security. However, the growth and success of the poultry industry also come with challenges and responsibilities. The escalating growth of the poultry sector has led to increased ammonia emissions and fly infestations, impacting humans and their environment. This research paper addresses these pressing challenges by proposing an innovative solution through the creation of a Smart Waste Management System for Poultry Farms that monitors and controls ammonia and fly infestations. Data were collected from agricultural offices, literature sources, and prior studies to inform the development of the system. The system will be implemented using a 16x2 Character LCD Module Display, MQ-137, DTH22, SIM900A GSM, IR Proximity Sensor, 5-Channel Line Tracking Sensor, Arduino Mega, fly zapper, and a conveyor for collecting chicken manure. This research presents a holistic approach to mitigate the negative effects of ammonia emissions and fly infestations in poultry farms, contributing to improved waste management practices and environmental sustainability.

1. 0 INTRODUCTION

The poultry industry has been responsible for fulfilling approximately one-third of the global meat consumption and fulfilling the whole demand for eggs during the past few decades. Moreover, it has gained recognition as a highly efficient sector within the livestock industry. According to the Philippine Statistics Authority (2023), the estimated chicken production for the period of January to March 2023 amounted to 470.21 thousand metric tons, measured in live weight. This figure indicates a 3.3 percent yearly rise compared to the output of 455.04 thousand metric tons, lightweight, during the corresponding period in 2022. However, this rapid growth results in a substantial environmental impact. Waste materials such as poultry litter and manure, have the potential to significantly harm both environmental and human health, necessitating appropriate management strategies. The emissions of ammonia, nitrous oxide, and methane are associated with poultry production and the disposal of its waste by-products. These emissions have significant implications for global greenhouse gas emissions, as well as the well-being of both animals and humans. (Gržinić et al., 2023)

Fly infestations, particularly house flies (Musca domestica), are particularly common in poultry farms and might present additional challenges. Flies possess the capability to disseminate diseases, contaminate poultry feed and water sources, as well as cause irritation and stress among chickens. According to International Pest Control (2018), the common housefly, Musca domestica, is a nuisance that is becoming increasingly common in animal shelters and farms all across The Philippines. The Department of Environment and Natural Resources (DENR) and municipal governments in the country closed a number of farms in 2017 owing to the nuisance caused by houseflies, primarily those raising chickens in conventional sheds. The problem is still a worry for growers and businesses as a whole and is frequently covered in the local media. Fly infestations from the poultry farms have spread to nearby cities and settlements, causing widespread public outrage.

According to Muduli et al. (2019), waste is commonly described as any material or substance that has lost its utility and requires proper disposal. Moreover, waste can be categorized based on its origin and location of generation, including agricultural, domestic, industrial, and mining waste. The poultry industry generates significant amounts of waste, encompassing both solid waste and wastewater. According to Antonov et al. (2019), one farm operation can create between 300 and 450 thousand tons of these organic wastes annually. Particularly, a typical poultry farm has the capacity to produce roughly 30 tons of manure every day. Chicken manure is hazardous to human health and are classified as a third-class environmental hazard by a number of current laws, including “on ecological expertise", and "on environmental protection".

This study aims to address the challenges pertaining to ammonia and fly infestations in a poultry farm in San Pioquinto, Malvar, Batangas by proposing an innovative approach focused on the creation of a smart waste management system. The proposed system is designed to efficiently monitor and control levels of ammonia and fly infestations in poultry farms. The suggested method aims to enhance sanitation techniques in poultry farms by incorporating automatic manure disposal using a conveyor system, as well as using a fly zapper that eliminates flies. This will contribute to the improvement of reducing ammonia and fly infestations in poultry farms.

2. 0 REVIEW OF RELATED WORK

2.1 Ammonia Monitoring in Poultry

One of the gases that are regarded to be hazardous in surroundings with livestock, particularly in situations with poultry farms, is ammonia. When the concentration of ammonia gas in poultry area reaches a particular level, it can lead to poisoning and potentially the death of the poultry if the concentration is allowed to continue to rise. To lessen the toll that ammonia gas takes on poultry populations, prompt and accurate analysis is required. As a result, a monitoring system was suggested that had the potential to monitor the state of the concentration of ammonia gas in the agricultural environment in real-time. The purpose of their project is to construct a wireless system network system that is capable of sending data to a web server over an internet connection. (Ashari et al., 2019)

Abdrakhmanov et al., (2020) stated that agriculture in Russia is growing quickly, especially in the areas of livestock and chickens. Even though these consumer markets are stable and full of food products, there are a number of problems directly linked to the growth of these areas, such as poor indoor and outdoor air quality, which affects animals, birds, and people in the same way. Almost every technology process used in modern production has some kind of control system. In agricultural businesses, a huge number of different systems are made and used. In their study, it is planned that the developed system will be able to control the amount of ammonia and show the current concentration readings. It will also be able to send data to a remote user and an integration with existing monitoring and control systems is being thought about. The system should also be easy to manage, easy to use, and, most importantly, cheap.

The majority of poultry farmers reuse poultry manure for multiple consecutive batches to minimize costs. This practice, however, can increase humidity and ammonia production. Broilers suffering from an excess of ammonia gas experience tension and disease. Therefore, the production of broilers can be reduced, resulting in losses for poultry producers. Consequently, continuous monitoring of the ammonia concentration in aviaries is required. In turn, the price of commercially available devices for performing this task is deemed to be excessive. So, their study devised a low-cost prototype for the monitoring of ammonia gas in aviaries. To achieve this, the NodeMCU module was utilized to measure the Ammonia gas concentration via sensors and send real-time data to a poultry farmer-accessible Android mobile application. The NodeMCU data is transmitted to a Spring Boot server and stored in a cloud database so the user can receive notifications when the ammonia level exceeds an acceptable threshold. (Brito et al., 2020)

According to Aunsa-Ard et al., (2021) malodor emission from chicken farms is a severe environmental concern. Their paper presents a fundamental investigation of malodor monitoring in poultry farms using gas detection equipment and an in-lab-built electronic nose (e-nose) system for measuring and analyzing livestock farm odors. This electronic nose is made up of eight gas sensors that have been precisely chosen to detect the principal volatile chemicals generated by animal farms. This e-nose's major components include a sensor chamber, a sensor array, a microprocessor, signal conditioning circuits, and wireless sensor networks. The e-nose system can also classify and measure distinct scents. The obtained data were interpreted using principal component analysis and the hierarchical cluster analysis pattern recognition approach. A chicken farm was researched in their paper employing a portable e-nose and an e-nose station capable of real-time odor monitoring. A gas detector was also used to measure ammonia, hydrogen sulfide, and volatile organic compounds. The results reveal that an electronic nose can identify the source of malodor, classify distinct scents, and monitor malodor in a chicken farm in real-time. Ammonia gas was discovered largely inside the chicken house, where it is the main source of stench.

2.2 Smart Poultry Farm

According to Naik et al. (2020), poultry is the most important economic food supplier business. Healthy poultry products are produced using sound farm management methods, with the purpose of satisfying consumers while also increasing corporate profit. Environmental variables have a significant influence on the production of healthy poultry birds. Standardizing environmental elements such as light, temperature, and humidity can improve chicken growth and productivity. The Internet of Things is used to monitor environmental conditions. To monitor the parameters, a prototype was created utilizing sensors inserted within the poultry. The managing and controlling operations are automated based on sensor data. The web page displays real-time sensor values that are refreshed every 5 seconds. Remote operation of the system is available by using the control choices offered on the web page, such as switching on the light or opening a window. The prototype is being tested on the farm. The environment can be controlled remotely.

As the Philippine population demanded a greater supply of food resources, chicken or poultry farms increased their output. The livestock industry is a multibillion-dollar industry on which many Filipinos depend. This investigation was conducted to address the need for providing poultry producers with modern technology. This study examines the Poultry Management System, an IoT system that automates the feeding and watering of poultry. The time at which the user intends to feed the poultry has been programmable via an Android application. Once the sensor detects that the water container is emptied, water is continuously supplied to the chickens. A notification system is in place to alert the user when the feed and water tanks reach a low level. The microcontroller and actuators are powered by a battery, which is charged by a solar panel. This technology improved the efficiency of poultry enterprises by saving time and effort. (Batuto et al., 2020)

In the study of Adha et al. (2022), poultry farming is one of Malaysia's greatest sectors and contributes significantly to the Malaysian economy. One of the reasons for Malaysia's rapid expansion of poultry farming is that chicken is the second most popular meat option among Malaysians and is acceptable to the country's multi-ethnic population. As a result, in order to remain relevant, the poultry sector must be continually profitable. The poultry industry's difficulty, however, is the inefficient use of technology resources to monitor birds, who are sensitive to temperature, humidity, and ammonia in the chicken farm. The locals grow chickens on chicken farms in the traditional manner. As a result, in an era where intelligent gadgets are mainly functional and accessible to people from all walks of life, their study has used new technologies to create chicken farms. It also proposes and develops a conceptual framework for a chicken farm monitoring system based on the Internet of Things, which can assist poultry producers in remotely monitoring the farm via their website.

Poultry farming goods play an essential role in delivering healthful, protein-rich meals to humans. The rapid increase in demand for poultry-based goods, combined with the advancement of information and communication systems, has resulted in intelligent poultry farms. The atmosphere of the poultry farm has a considerable impact on the health of the chickens as well as the farm's production. A low-cost edge computing and Internet of Things (IoT)-based solution for chicken farms will handle the farm environment and disease control with minimal human participation. The model will detect the temperature, humidity, greenhouse gases, and light intensity within the chicken farm and relay these readings to a local server built with the Raspberry Pi. Data is processed at the local server using edge computing, and intelligent information is retrieved to manage the numerous actuators inside the farm. Because of the use of low-cost computing devices such as Raspberry Pi, the method is inexpensive for farmers. (Garg et al., 2023)

2.3 Smart Waste Management in Poultry

In the study of Arago et al. (2018), the poultry industry has always been a significant contributor to livestock revenue in the Philippines agricultural sector. However, poultry farms frequently emanate odors from chicken manure, which can have detrimental effects on both local residents and chickens. Utilizing effective microorganisms (EM) is one solution to this problem. EM is a low-cost, non-harmful, non-pathogenic, and non-genetically modified waste remediation solution. In this study, the researchers created a system that autonomously detects the toxicity of gases and reduces both the toxicity and odor by spraying an activated EM solution. Moreover, the spray schedule is optimized using data analytics techniques. Results demonstrate that the system consistently reduces toxicity levels in poultry houses where it is implemented.

According to the research conducted by Jose et al (2020), due to the accumulation of manure, many farms encounter labor shortages and environmental problems. Manually cleansing manure to reduce pollution is problematic from a practical standpoint. The areas that are regarded as automated in this paper are egg collection and manure disposal. Automation in these areas can save considerable time and labor costs. This will also improve hygiene within the poultry farm, reducing the incidence of disease among the birds. A combination of software and hardware systems can be utilized to automate the labor-intensive tasks within the farm. Increasing the efficiency of the farm can be accomplished by maintaining the optimal conditions for poultry growth. This paper proposes a model that monitors and regulates multiple environmental parameters, such as temperature, ammonia level, and humidity, in poultry farms to maintain an optimal environment. Due to variations in humidity and temperature, natural incubation generates a lesser number of chicks. A solar-powered automated incubator is also designed with a mechanism for egg rotation and environmental parameter controls. Thus, the system concentrates on maximizing agricultural output with minimal labor and minimizing pollution.

Using machine learning algorithms in conjunction with the Internet of Things has been suggested as a solution to the problem of managing poultry waste. An android application is used to serve as an interface between poultry farms and poultry waste management organizations in order to cut down on the amount of trash produced by poultry. Devices powered by the Internet of Things are installed in waste containers, and these devices provide real-time data regarding the smart bin. The use of information and communication technology (ICT) enables poultry farms to exchange information with businesses that handle the disposal of chicken waste and to offer these organizations services of a high standard. (Aashvina et al., 2022)

In a recent study conducted by Chang et al., (2022), it is said that the majority of the layer breeding industry has shifted from traditional outdoor or courtyard feeding to highly automated cascade poultry cage breeding. Now it must revert in part to its natural stocking method. The unrestricted stocking mode of breeding can significantly enhance the activity space and welfare of layers. The automatic cascade poultry cage has the capabilities of cleaning chicken droppings and collecting eggs, which are unavailable in the natural stocking mode of a chicken coop. In this paper, STM32 is used as the primary controller and a mechanical device capable of automatically collecting eggs and cleaning chicken manure is designed for a chicken coop with a natural stocking level. The device consists primarily of a screen, a push rod, a conveyor belt, an egg collection tank, and a manure collection tank. Through the screen, the chicken manure descends onto the conveyor belt. The conveyor belt transports poultry manure to the collection tank for chicken manure. The egg is forced into the egg collection tank when the rod is pushed forward. Simultaneously, the brush on the rod can clean the chicken manure left on the screen, which reduces manual labor, and the solar panel addresses a portion of the power consumption problem. The system uses the touch screen as its primary control method, implements the UI design, displays the temperature and humidity on the screen, controls the opening and closing of the fecal cleaning and egg collection device, fills the light, buzzer, and exhaust fan by touching the screen, and also has mobile phone remote control functionality.

3.0 METHODOLOGY

3.1 Methods of Data Collection

The initial step in the implementation of the Smart Waste Management System in Poultry Farms involved the collection of data from the agricultural offices in the municipalities of Malvar and Balete. This was done to find out whether there are any pre-existing systems that specifically target concerns related to ammonia emissions and fly infestations.

The researchers also collected data from a variety of related studies and literature gathered from different sources, including IEEE papers, internet sites, and recent research. The researchers used several sources of information and data to identify important qualities and areas necessitating improvement within our Smart Waste Management System in Poultry Farms. The researchers also considered the recommendations and ideas given by their thesis adviser.

3.2 System Development Flow

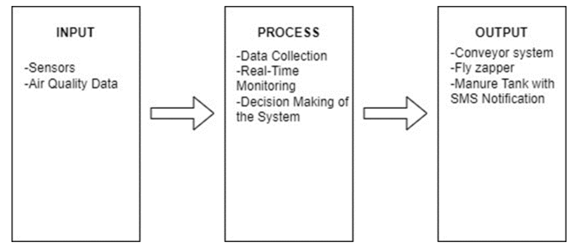


Figure 1. Conceptual Framework

The input consists of sensors that provide constant monitoring of ammonia levels, temperature and humidity that contribute to the mitigating the potential for fly infestations, along with the collection of air quality data.

The process of the system involves data collection, where the sensors gather real-time data on ammonia levels, temperature, and humidity. This data is then processed to analyze the air quality in the poultry farm, specifically focusing on the levels of ammonia and the presence of flies. Real-time monitoring is implemented to continuously track and update the air quality data. The system also includes decision-making capabilities to determine the appropriate actions to be taken based on the collected data.

The output of the system includes the conveyor system that transports the manure to the tank, an SMS notification to notify the farmer when the tank is full. Also, the system has fly zappers that is turned on the whole day to eliminate flies and reduce infestations in the poultry farm.

3.3 Verification Plan

This study's verification plan will comprise of two phases. First is validation testing. The system is going to be tested to determine whether or not it generates all of the required outputs. The sensors will be evaluated in light of their respective functions. The system must be able to accurately determine whether the ammonia level, together with the humidity and temperature, varies depending on the conditions of the environment. Moreover, the conveyor system must be working effectively and turns on during its programmed schedule and test if the tank will be able to get all the manure waste coming from the conveyor. In addition, the fly zappers should also be working and is able to eliminate flies effectively. The second phase is the prototype testing. Prototype testing involves deploying the smart poultry system with ammonia, temperature and humidity sensors, an Arduino microcontroller, and a manure waste conveyor in the chicken coop to assess its functionality and performance. Data is collected on ammonia emissions, temperature, humidity, and other environmental parameters in both clean and loaded coop conditions. The system should send SMS to the farmer, ensuring timely actions can be taken. Performance and reliability are evaluated, and improvements are made based on testing results to optimize the system's functionality and effectiveness in maintaining a healthy and comfortable environment for the chickens.

4.0 RESULTS AND DISCUSSION

4.1 Design a system that measures and monitors ammonia, humidity, and temperature in poultry farms.

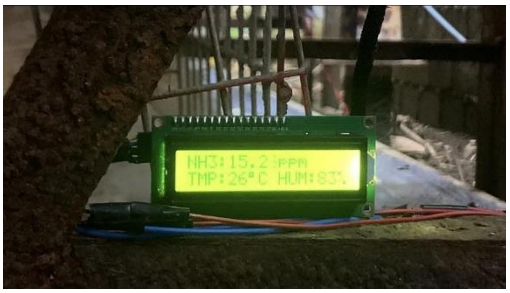


Figure 2. Sensor Display

The MQ-137 sensor for ammonia measurement and DHT22 for temperature humidity is connected to the microcontroller (Arduino). This setup enables automated control based on the sensor's readings. Necessary codes and libraries were incorporated to handle sensor calibration for accurate measurements, especially for the MH137.

The sensors have been placed in the middle of the chicken coop. Their primary function is to record and monitor data on different environmental parameters over a prolonged period of time. The sensors are able to record and track any variations or shifts in these parameters within the poultry farm.

4.2 Integrate a conveyor system with a tank for collecting manure and a SIM module for SMS notifications.

Manure collection and storage in a regulated environment is managed by the conveyor in the intelligent control system. Either when the time scheduled for its operation comes around or when ammonia levels are high, no matter what time of day, are the two triggers that set it off. The conveyor will start transferring manure from the surrounding area to the tank as soon as one of these requirements is satisfied.

The system continuously monitors the manure container to track its fill level. If the container becomes full, the conveyor will stop running, even if one or both activation triggers are present. This helps prevent overfilling and potential issues with the storage of manure. Additionally, the system notifies the owner when the container is full, prompting them to empty it.

Once the container is emptied and the tank sensor detects that it is no longer full, the conveyor can resume operation if either of the triggers (scheduled time or high ammonia levels) is present. This approach ensures that manure is collected efficiently while preventing overflows and maintaining a clean, healthy environment for the chickens and humans in the controlled space.The conveyor is constructed utilizing a tarp, PVC pipe, and bearings, forming a 25-foot conveyor system. The decision to utilize a tarp, as opposed to traditional metal sheets and rollers, was driven by the need for a cost-effective solution. Given the considerable length of the conveyor (25 feet), opting for a tarp material was a strategic choice to manage costs efficiently.

Figure 3. Conveyor System

The operational cycle of the conveyor, denoting the time it takes to complete one full round of manure transfer to the tank, is established at a duration of 15 seconds. After a single operating cycle, the system effectively transports and deposits all of the chicken manure into the tank, demonstrating its efficiency. This reliable and timely transfer process ensures swift and effective waste management in response to elevated ammonia levels.

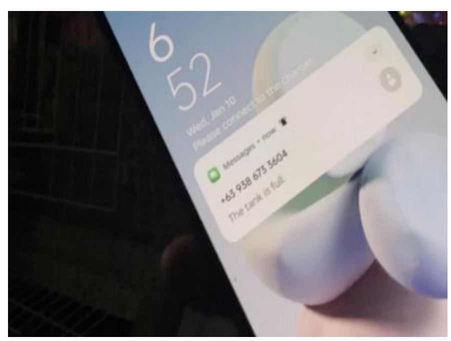


Figure 4. SMS Notification

To further improve user awareness and engagement, the system also includes an extra feature. The built-in SMS alert system is activated when the infrared proximity sensor detected that the tank reaches its full level. This function acts as a proactive alarm system, alerting the user as soon as the tank fills up. The deployment of SMS notifications not only keeps the user informed about the status of the waste collection but also allows for timely intervention, promoting an optimal waste management strategy.

4.3 To utilize a fly zapper for the effective elimination of flies within the area.

The fly zapper is designed to remain in an active state at all times, ensuring continuous functionality to effectively eliminate flies that come into contact with it. The zapper operates by electrocuting the flies upon contact, providing an efficient and instantaneous method of pest control.

Figure 5. Fly Zappers

Three fly zappers are positioned strategically around the chicken coop to improve fly elimination coverage and efficacy. The area is well-covered to target flies from different directions with one zapper on the left, another on the right, and at the center. This thorough distribution makes it more likely that flies entering the chicken coop from any direction will come into contact with a zapper, leading to a higher likelihood of electrocution and elimination.

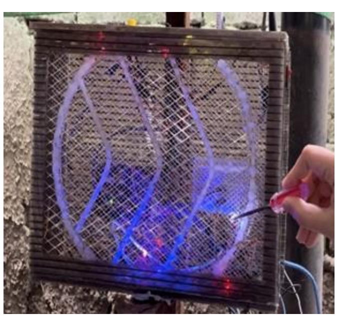
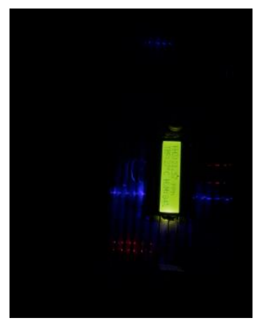


Figure 6. Testing of the Fly Zapper

For the testing phase, we conducted experiments as depicted in Figure 5.5. The goal was to assess the fly zapper's performance in a controlled setting. In particular, conductor materials—like metal—were used to determine if the zapper exhibited any sparking or short circuits during contact with foreign objects. The purpose of this controlled experiment was to simulate situations in which flies or other flying insects come into contact with the zapper while it was in operation.

4.4 Evaluate the system's effectiveness in the decrease in ammonia levels and fly infestation before and after implementation.

(a)



(b)

(c)

Figure 7. Data Gathering on Ammonia Level (a) Day 1, (b) Day 2, (c) Day 3

Figure 7 illustrates the significantly elevated ammonia levels in the poultry farms prior to the waste management system's installation. This elevated concentration of ammonia, often associated with the decomposition of chicken manure, presented a significant environmental concern.

Following the implementation of the system, specifically designed for efficient chicken manure disposal, every time the conveyor transports the manure to the tank and is disposed efficiently, a substantial decrease in ammonia levels was observed.

(a) (b) (c)

Figure 8. Data Gathering – Flies (a) Day 1, (b) Day 2, (c) Day 3

Figure 8 provides insights into the fly infestation situation before the implementation of the waste management system. Sticky fly traps were put strategically across the vicinity in order to provide for a quantitative evaluation that allowed for an approximation of the fly populations in the area.

A significant decrease in the quantity of flies was seen after the system—which has fly zappers in addition to efficient waste disposal techniques—was put into place. This decrease is explained by the system's capacity to draw in and get rid of flies, improving the environment's sanitary conditions. Incorporating fly zappers has shown to be a very successful strategy for reducing fly populations in the chosen area. Fly that comes into contact with the zapper eliminates were electrocuted, thus reducing the fly population. This particular approach has been essential in mitigating the fly infestation, hence making a significant contribution to the overall decrease in fly populations around the area.

(a) (b) (c)

Figure 9. Testing – Flies (a) Day 1, (b) Day 2, (c) Day 3

The table below shows the number of flies before and after the smart waste management system was implemented in a poultry farm for three days. The "Percentage Reduction" column shows the percentage decrease in the number of flies after the system was implemented. The calculation is performed by subtracting the value of no. of flies (after), from the value of no. of flies (before), then dividing by the "No. of Flies (Before)" value, and finally multiplying by 100.

$$Percentage\ Reduction = \frac{No.of\ Flies\ (Before) - No.of\ Flies\ (After)}{No.of\ Flies\ (Before)} x\ 100$$

Table 1. Fly Population in Poultry Farm before and after Smart Waste Management System Implementation.

Day	No. of Flies (Before)	No. of Flies (After)	Percentage Reduction
1	499	55	88.98%
2	333	51	84.65%
3	380	76	79.74%
Average	404	61	84.12%

5.0 CONCLUSION

Based on the work accomplished in this study, the following conclusions have been made by the researchers:

- Waterproof Trapal can be used as an alternative to metal sheets in creating a low-cost conveyor system.
- The conveyor system is effective in properly disposing the chicken manure.
- Ammonia level gradually decreases when the chicken manure is not present within the area.
- The integrated fly zappers effectively eliminates and reduces flies in the poultry farm.
- The built-in SMS notification system keeps users informed about waste collection and tank capacity.

To sum up, the Smart Waste Management System for poultry farms offers a thorough solution to the complex issues brought on by the waste generated by the industry. The system that has been designed presents a significant progress in addressing environmental and sanitation issues in poultry farms. Its ability to minimize fly populations and reduce ammonia emissions makes it an effective strategy for encouraging environmentally friendly and ethical poultry farming practices. The integration of modern technology, real-time monitoring, and automated responses has the potential to transform waste management processes. This could lead to enhanced environmental sustainability and cleanliness in poultry farms.

6.0 RECOMMENDATIONS

Following the completion of the smart waste management system, the researchers present the following suggestions:

- Explore the use of low-power sensors and energy-efficient actuators to reduce overall system energy consumption. Consider solar panels as alternative power sources for long-term sustainability.
- Research and deploy advanced sensors for more accurate and comprehensive monitoring of ammonia, humidity, temperature, and fly populations.
- Implement algorithms that modify system behavior in response to real-time data. To maximize resource efficiency and efficacy, this could involve adjusting conveyor speed and fly zapper activation in response to fly activity and ammonia levels.
- Explore integrating additional functionalities for managing the collected manure

7.0 ACKNOWLEDGMENT

The proponent expresses profound gratitude to all those who contributed to the completion of this project. Sincere thanks are conveyed to Engr. Adonis S. Santos, Engr. Marco Alejandrino, and Engr. Kent Patrick Ferraro for their unwavering support, invaluable guidance, and continuous encouragement throughout the thesis journey. Additionally, the proponent extends gratitude to the chosen beneficiary, Konsehala's Farm by Miss Edna Pitogo in Kapitan Maria, San Pioquinto, Malvar, Batangas, for their cooperation and participation. Lastly, heartfelt appreciation is extended to family and friends for their constant encouragement, understanding, and patience. Their unwavering support and faith were instrumental in overcoming challenges and completing this research paper. While not all contributors can be named individually, the assistance of everyone who supported this research, directly or indirectly, is deeply appreciated.

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9.0 ABOUT THE AUTHORS

The researchers are graduating students of FAITH Colleges, pursuing a Bachelor of Science in Electronics Engineering. Jade Emmanuel Dela Pena is currently an engineering intern at Sohbi Kohgei (Phils.), Inc. Guia Jazle Orzo is serving as a Failure Analysis Intern at On Semiconductor Philippines Inc. Lastly, Ada Betina Villegas is interning in the modules department at Fastech Synergy Philippines Inc.

10.0 APPENDIX

Appendix A – Bill of Materials

Quantity	Materials	Costs
3	Gi Square Tube	₱1,950.00
2	Gi Pipe	₱800.00
3	Orange pipe	₱660.00
3	Mosquito Swatter	₱531.00
1	Waterproof Trapal	₱308.00
18	KRX Motorcycle Bearing	₱630.00
1	Infrared IR Proximity Sensor	₱25.00
1	5-Channel Line Tracking Sensor	₱149.00
1	1602 16x2 Character LCD Module Display HD44780 with I2C	₱149.00
1	220 AC Motor	₱750.00
1	5V 4-Channel Relay	₱159.00
1	Sim900A	₱180.00
1	Arduino Mega	₱850.00
1	MQ137	₱799.00
1	DHT22	₱195.00
	Total	**₱8,135.00**