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# Utilization of Hygrometer and Exhaust with Internet of Things (IoT) Technology in Temperature Control of Maggot (BSF) Containers

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## Abstract

The growing global focus on sustainability has driven advances in waste management, including the use of Black Soldier Fly (BSF) larvae to convert organic waste into high-protein material for animal feed. This research introduces an Internet of Things (IoT)-based system designed to optimize temperature and humidity control in a maggot farm environment. By integrating hygrometers and exhaust systems with IoT technology, the system provides real-time monitoring and automatic adjustment, maintaining an optimal temperature range of 28°C to 31°C to support larval growth and productivity. This study used the Quality Function Deployment (QFD) method to incorporate the needs of maggot farmers into the design process. Primary data were collected through questionnaires, while secondary data from relevant literature on waste decomposition, IoT applications, and maggot farming were used for analysis. Using these data, a House of Quality (HOQ) framework was developed to guide the design of a biopond system equipped with temperature sensors and automatic fans. This approach increases maggot productivity, minimizes methane gas buildup, and is aligned with the goals of Sustainable Development Goal (SDG) 12, which promotes responsible consumption and production. This study highlights the potential of IoT technology to improve agricultural practices and support sustainable maggot farming.

## 1. Introduction

The development of technology today motivates humans to continue to think creatively, both in making new discoveries and maximizing the performance of technology to help ease human work in everyday life. In addition to helping with daily work, technology can be used to help farmers in monitoring the temperature in their livestock cages. One of them is the Maggot BSF (Black Soldier Fly) cage using Exhaust and Hygrometer. Temperature control is needed to continue the growth of maggot livestock to be maximized. BSF maggots develop in the second metamorphosis phase before the pupa phase and after the egg phase, then they become adult BSF (Waluyo & Nugraha, 2020). The utilization of maggot is commonly used as animal feed for fish and poultry, in addition to animal feed, maggot breeding is one of the fastest efforts to break down organic waste. The protein possessed by maggot is so high that it is good for animal feed. Maggot has a protein content of 40% at the age of 35 days, at the age of 6 to 7 days the protein content in maggot reaches 60.2%, fat 13.3%, carbohydrate 18.8%, ash 7.7% (Irawati & Ningsih, 2024). The high nutrition of maggot and its abundant availability and easy and useful breeding is one of the excellent potential alternatives for breeding. One of the main advantages of BSF maggot is its resistance to organic matter that can be used as a substrate.

The increasing global focus on sustainable practices has driven innovations in waste management and resource optimization, including the cultivation of Black Soldier Fly (BSF) larvae, commonly referred to as maggots. These larvae are valued for their ability to convert organic waste into high-protein biomass, which can be used as animal feed. However, maintaining optimal environmental conditions such as temperature and humidity within BSF containers is critical for their growth and waste conversion efficiency. Emerging technologies, including the Internet of Things (IoT), have shown great promise in automating and optimizing these conditions. According to (Juyal & Rautela, 2023), implementing advanced humidity control methods using fuzzy logic can significantly improve workplace environments, which can be extrapolated to applications in BSF containers.

Temperature and humidity control in maggot farming presents unique challenges due to the dynamic nature of biological processes. Traditional methods of monitoring and control often fail to provide the precision required for maintaining ideal growth conditions. Internet of Things (IoT)-enabled devices, such as hygrometers and exhaust systems, offer real-time monitoring and adaptive adjustments, addressing these challenges effectively. As highlighted in (Yudhana, 2023), the effectiveness of the Tsukamoto fuzzy inference system in Internet of Things (IoT)-based applications for controlling room temperature and humidity emphasizes its potential for precision agriculture and maggot farming.

The role of exhaust systems in managing air quality and temperature cannot be understated, especially in closed environments like BSF containers. (Adziimaa, Ardiatmajaya, & Utami, 2023) designed a prototype for automatic exhaust fan speed control based on Internet of Things (IoT) technology, demonstrating its efficacy in maintaining indoor air quality. Incorporating such systems into maggot farming setups ensures that the buildup of heat and humidity, which could hinder larval growth, is effectively mitigated.

Internet of Things (IoT) technology not only enhances environmental control but also enables predictive maintenance and alert systems. (Saha, Das, & Banik, 2022) discusses the application of Internet of Things (IoT) in smart greenhouses for monitoring and controlling temperature, soil, and humidity. These principles can be adapted to BSF containers, where consistent environmental conditions are crucial. The integration of sensors, data analytics, and automated control mechanisms ensures that deviations from optimal conditions are promptly addressed, minimizing risks to larval development.

Another advantage of Internet of Things (IoT) integration in maggot farming is the scalability and customization of the systems. (Rashim et al., 2023) describes the use of the Growth Monitoring System (GMonS) in agriculture, which provides valuable insights for monitoring plant growth. A similar system could be tailored for maggot farming, offering data-driven solutions for optimizing environmental parameters. This customization allows for adjustments based on the specific needs of the BSF lifecycle, ensuring efficient resource utilization.

The combination of hygrometers, exhaust systems, and Internet of Things (IoT) technologies creates a robust framework for managing the microclimate within BSF containers. (Juyal & Rautela, 2023) emphasizes the importance of precise humidity calculations in enhancing workplace efficiency, a concept directly applicable to maggot farming. By leveraging Internet of Things (IoT)-enabled hygrometers, real-time data can be collected and processed to maintain ideal humidity levels, thereby enhancing larval productivity and waste conversion rates.

The utilization of Internet of Things (IoT) technologies, such as hygrometers and exhaust systems, revolutionizes temperature and humidity control in BSF containers. By integrating advanced fuzzy logic algorithms, real-time monitoring, and automated responses, these systems provide an optimal environment for maggot cultivation. The studies by Juyal and Rautela (2023), Yudhana (2023), Adziimaa et al. (2023), Saha et al. (2022), and Rashim et al. (2023) collectively underscore the transformative potential of Internet of Things (IoT) in agricultural and waste management practices, paving the way for more efficient and sustainable maggot farming solutions.

Maggot BSF is a larva that has a high appetite with the ability to break down waste mass by 52% - 56% of organic waste mass (Salman, Noviyanti, & Nurfadillah, 2020). The media where maggot lives is Biopond which is used to accommodate maggot in decomposing organic waste. A Biopond environment that does not support the comfort of maggots will shorten the life cycle of maggots, especially the waste decomposed by maggots produces methane gas which causes heat in the maggot container and can cause maggots to become uncomfortable in Biopond containers and accelerate the maggot life cycle. The average maggot life cycle is 45 days depending on environmental conditions and food. Ideal temperature comfort makes maggots more productive and attempts to prevent premature death in maggots (Singkih & Putra, 2024). When Maggot carries out the process of decomposing organic waste in a tightly closed Biopond, the methane gas produced from the decomposition process will turn into dew and cause the temperature to increase hotter. If the temperature is too hot, the maggot will come out of the Biopond container. A good temperature for maggot is between 28℃ - 31℃ (Noviant, 2023). An environment with an optimal temperature can affect the life cycle and productivity of maggots and support maggot growth.

Based on the above problems, an alternative solution is needed to prevent premature death in maggots, by integrating temperature and exhaust gauges in technology-based maggot containers, namely Internet of Things (IoT). Internet of Things (IoT) itself is a database system for updating and storing data, with the advantages of the Internet of Things (IoT) system that helps which is stored in the database of data results from sensor detection on a device and integrated. Internet of Things (IoT) as a network connection system that connects physical and virtual objects through data processing and network technology is defined as a system with objects that are placed sensors and connected to the server. The main concept of Internet of Things (IoT) includes 3 elements, namely, physical objects that have been programmed on sensor modules, internet connections, and databases on servers to store data or information from the internet (Lisnawati, 2022). Hygrometer and Exhaust tools programmed using the Internet of Things (IoT) system can help the development of maggot in Biopond with sensors embedded in Exhaust as a temperature controller and work automatically when the temperature in Biopond detected by Hygrometer reaches the maximum temperature of maggot resistance in biopond.

The design of tools using sensors connected to the hygrometer and exhaust can be a new innovation to make maggot places have a more optimal function. The focus of the connection between the hygrometer and exhaust on the biopond container is when the BSF maggot decomposes organic waste and produces methane gas which makes the temperature rise in the biopond then the sensor attached to the hygrometer will read the temperature, and forwarded to the exhaust sensor which will automatically turn on if it is more than 31 ° C and the exhaust will automatically stop when the temperature has reached below 28 ° C. The solution to utilizing Internet of Things (IoT) technology can help control heat and eliminate methane gas. The solution to utilizing Internet of Things (IoT) technology can help control heat and eliminate methane gas by using Hygrometer as a temperature gauge and Exhaust as a temperature controller that is innovated with Internet of Things (IoT) technology by integrating a database system so that the results of decomposing organic waste in the form of methane gas that settles in Biopond can come out through Exhaust installed in Biopond and maggot breeding can be more optimal.

Utilizing digital technologies such as Internet of Things (IoT) helps reduce costs and losses for maggot farmers, resulting in additional income and better maggot development, as well as opening doors to new markets in line with the UN Sustainable Development Goal (SDG's 12). SDG's chapter 12 is about responsible consumption and production. The application of Internet of Things (IoT) technology that contributes to sustainability is economic, environmental, and social (Amirya, 2023). By applying the concept of SDG's, the research on Biopond maggot containers combined with Internet of Things (IoT) technology is directly connected to SDG's chapter 12. This innovation enables more efficient use of resources, connectedness through Internet of Things (IoT) integration, and increased sustainable production in the context of maggot production. Thus, this research not only offers a creative solution to improve the efficiency of Biopond, but also relates to the principles of responsible production and consumption in accordance with chapter 12 of the SDGs.

## 2. Material and methods

### 2.1. Material

This study uses Black Soldier Fly (BSF) maggot as the main decomposer in an Internet of Things (IoT)-based biopond designed to optimize environmental conditions. The biopond is made of thick plastic with a lid to control air circulation, equipped with temperature and humidity sensors connected to an Internet of Things (IoT) system. An automatic exhaust fan is used to maintain optimal temperature and humidity based on sensor data sent to the cloud.

Figure 1. Biopond Cover Framework

The construction of the biopond enclosure starts with making holes for food pipes and air vents. The location of the holes is determined based on operational needs, such as ease of access for feed and optimal air circulation. The food pipe holes are placed so that feed can be evenly distributed, while the ventilation holes are arranged to support airflow and prevent the buildup of harmful gases. Once the holes are created, the food pipe and ventilation system are carefully installed, ensuring a tight seal and protection against outside contaminants.

Figure 2. Feeding Pipe and Pipe Cover

Once the hole for the biopond cover frame is complete, a 2-inch diameter pipe is cut 30 cm long to create a food channel. The pipe is measured and marked with precision before being cut using a saw or pipe cutting tool. After cutting, the edges of the pipe are trimmed to avoid obstructing food flow and ensure safe installation. The cut pipes are then inserted into the holes provided on the biopond cover frame, with a tight seal to prevent leakage.

Figure 3. Pipe cross-section

After cutting the food channel pipes, the next step was to cut the pipes for the biopond cross-section, which serves as the main structural component. The length and number of pipes are adjusted to the size of the planned biopond. The pipes are measured, marked and cut using a hacksaw or pipe cutting tool, ensuring that each cut is of a consistent length and flat surface. The edges of the cut pipes are then trimmed to remove burrs, ensuring safe and proper installation in the biopond structure.

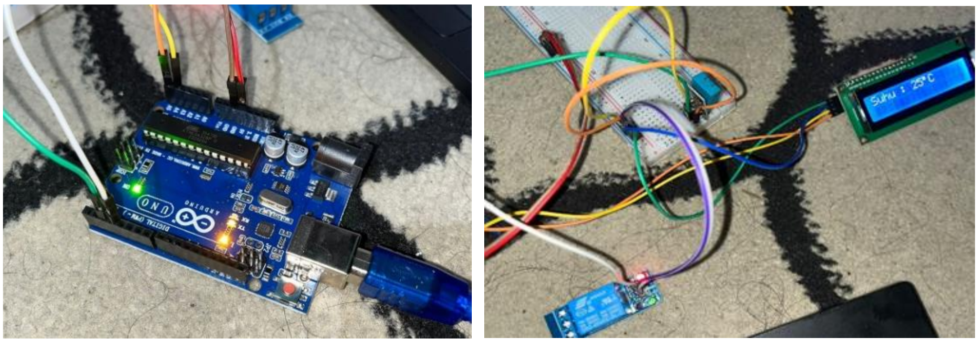


Figure 4. Internet of Things (IoT) System

Making an Internet of Things (IoT) system that is integrated with temperature and exhaust sensors in maggot containers. The Internet Of Things (Internet of Things (IoT)) system uses Arduino Uno R3 which connects to the internet to collect, send, and receive Internet of Things (IoT) data using Arduino Uno IDE 2.3.2 software and controls relays. The temperature sensor is mounted on the breadboard and jumper cables are attached to the relay, Arduino uno R3, breadboad and Lcd.

### 2.2. Methods

This study utilizes the Quality Function Deployment (QFD) method, a systematic approach designed to transform customer needs and preferences into technical specifications that guide product design, manufacturing, and production planning. QFD provides a structured process to ensure that customer requirements are integrated into every stage of product development. The method involves identifying customer needs, calculating their importance, determining product positioning, and using this information to develop a House of Quality (HOQ). The HOQ acts as the core tool within the QFD framework, serving as a matrix to prioritize customer requirements and translate them into technical solutions. It converts qualitative customer input into measurable data, enabling the design of products that align closely with user expectations. This approach is particularly effective in creating customer-focused solutions that address specific needs.

In this research, questionnaires were distributed to maggot farmers to collect primary data about their preferences and requirements for innovations in maggot farming systems. This data was critical for identifying factors that influence maggot farming productivity, particularly the control of environmental variables like temperature and humidity, which are essential for optimizing production. The analysis of this data informed the construction of the HOQ, ensuring that the proposed solutions were tailored to the needs of maggot farmers.

In addition to primary data, secondary data were gathered from literature on waste decomposition, maggot growth, methane gas management, Internet of Things (IoT) applications, and previous uses of QFD in agricultural practices. The incorporation of IoT into the QFD framework was a significant focus, as it enables real-time monitoring and automation of environmental conditions, such as temperature and humidity, to improve efficiency and productivity in maggot farming.

By applying the QFD and HOQ methods to maggot farming, this study addresses the practical needs of farmers while also contributing to sustainable innovations in waste management and alternative protein production. This approach bridges the gap between user-driven requirements and technical feasibility, promoting advancements in agricultural systems and production methods.

## 3. Results and discussion

Figure 5. Biopond

The picture above is the final result of the biopond. The performance of the Internet of Things (IoT)-based biopond can be categorized as successful if it is able to maintain the temperature and humidity of the environment inside the biopond at an optimal level between 28°C and 31°C, which is necessary to support maximum maggot growth and productivity. The system works by utilizing hygrometer sensors to monitor temperature and humidity periodically. The data collected by the sensor is then sent to the exhaust control system. When the temperature exceeds the optimal limit, the exhaust will activate automatically to lower the temperature, and will stop operating once the temperature returns to the desired range. The utilization of Internet of Things (IoT) technology allows the data obtained from the sensors to be stored and monitored in real-time via the internet network. This makes it easier for users to monitor the condition of the biopond remotely, thus reducing the need for intensive manual monitoring. In addition to maintaining the environmental conditions of the biopond, the system also increases the efficiency of the organic waste decomposition process, with the decomposition rate reaching 52% - 56% of the total waste mass. The success of the system can be measured by consistent temperature stability, increased maggot productivity, and efficient use of energy by the device.

## 4. Conclusion

In conclusion, this research successfully produced an Internet of Things (IoT)-based biopond design that aims to improve the efficiency of organic waste management and support the productivity of Black Soldier Fly (BSF) larvae. This design utilizes temperature and humidity sensors connected to an IoT system to monitor and control environmental conditions automatically. Although this research has not involved data processing or empirical trials, the proposed design shows potential as an innovative solution for sustainable organic waste management. The system can increase maggot productivity, reduce methane gas accumulation, and support the achievement of Sustainable Development Goal (SDGs) 12, which emphasizes responsible production and consumption. This Internet of Things (IoT) technology offers a new way of optimizing environmental conditions for more efficient and environmentally friendly maggot farming.

**Credit authorship contribution statement**
**Dr. Dino Rimantho:** Supervisor
**Alvin Rizki Ramadhan:** Material Preparation
**Trisya Puteri Azzahra:** Material Preparation, Prototyping, Data Analysis, Writing
**Kristina Maharani:** Prototyping, Data Collection, Data Analysis, Writing

**Declaration of Competing Interest**
The authors state that personal relationships may influence the work reported in this paper.

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