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# Bokashi-Based Home Composter for Fertigation System

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**Abstract:** Organic waste management is a huge problem coming from residential homes throughout the country. Improper decomposition of waste generates methane, which contributes significantly to the environment in terms of greenhouse effects. The proposed solution is the Bokashi-Based Home Composter for Fertigation System as a medium of Internet of Things (IoT). This system is designed to help users initiate composting through Bokashi composting and automated fertigation. Bokashi composting involves using airtight containers, Bokashi bran, and organic waste, which undergoes anaerobic fermentation to produce Bokashi Tea - a liquid by-product used as a fertilizer. The system architecture features an ESP32 microcontroller, soil moisture, humidity, and temperature sensors, as well as pumps for dosing and irrigation, all controlled through an application dashboard. The final product assembly successfully achieved its objectives to produce Bokashi Tea in less than 14 days and utilize it by dosing it to water with ratio of 1:100 with flow a flow rate of 1.6 ml/s and main pump flow rate of 32.5 ml/s for fertigation purposes in residential homes. The system is complemented by an application dashboard that provides IoT functionality, where the hardware parameters can be monitored and controlled by the application through Wi-Fi connectivity. This paper explores the process of product design.

**Keywords:** Bokashi composting, fertigation, irrigation, organic waste management, internet of things



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## 1. INTRODUCTION

Organic waste refers to biodegradable materials originating from living organisms. These materials include food waste, garden waste, agricultural waste, animal waste, and wood waste. Unlike inorganic waste such as plastics and metals, organic waste can be broken down by microorganisms such as bacteria and fungi into simpler substances [1]. Although the breakdown process of organic waste is faster than that of inorganic waste, it still plays a significant role in environmental degradation. When organic waste is disposed of in landfills, it decomposes anaerobically, producing methane, an extremely potent greenhouse gas. Methane emissions from landfills significantly contribute to climate change [2]. Additionally, organic waste occupies valuable space in landfills, which is a pressing issue in densely populated areas where land is scarce. Reducing the volume of organic waste that ends up in landfills can extend the lifespan of existing landfills and reduce the need for establishing new ones. Managing landfills is also an expensive process, leading some countries to export their waste to others to save on costs [3].

According to The Malaysian Reserve in 2023 [3], food waste is the third-largest source of greenhouse gas emissions, with a staggering 931 million tons of food wasted globally each year. This trend poses a significant threat to the environment if it continues. Raising awareness about the environmental impact of food waste and encouraging waste reduction are crucial steps in mitigating these effects. However, many people remain unaware of how their actions contribute to environmental degradation. Therefore, composting practice is an excellent method for reducing organic waste sustainably and environmentally friendly [4, 5]. It transforms organic waste into nutrient-rich soil through the natural decomposition process facilitated by microorganisms. Kitchen and food scraps, such as fruit and vegetable peels, coffee grounds, eggshells, and leaves, can all be composted. When placed in the right conditions, microorganisms thrive and break down organic matter efficiently, producing high-quality and nutrient-rich compost in a shorter amount of time that can promote healthy plant growth [4, 5, 6].

There are various composting methods, including traditional aerobic composting, vermicomposting, and anaerobic Bokashi composting. Aerobic methods require turning and oxygenation, while vermicomposting utilizes worms. The Bokashi method was selected for its efficiency in processing a wide range of organic waste, faster decomposition, and ability to produce nutrient-rich by-products with minimal odor.

Mujiyanti et al. [8], which focused solely on accelerating compost production, this system combines real-time monitoring, precise nutrient delivery, and automated irrigation, enhancing overall efficiency. Additionally, Jayashanker & Othman [9] presented an IoT-based fertigation for smart farming, this study uniquely integrates Bokashi composting as a sustainable fertilizer source, bridging the gap between waste management and smart agriculture. Hence, this developed Bokashi system integrates a more comprehensive IoT-enabled fertigation approach that optimizes both the composting process and automated fertilization.

The fertilizer will promote sustainable agriculture, utilizing waste by-products to enhance soil health and plant growth efficiently. In order to justify the project design, research was done to identify the relevance of Bokashi composting in home composting practices, and other available solutions to compare and identify the proper niche of this project.

## 2. METHODOLOGY

### 2.1 Bokashi Composting

Figure 1 shows the Bokashi composting procedures.

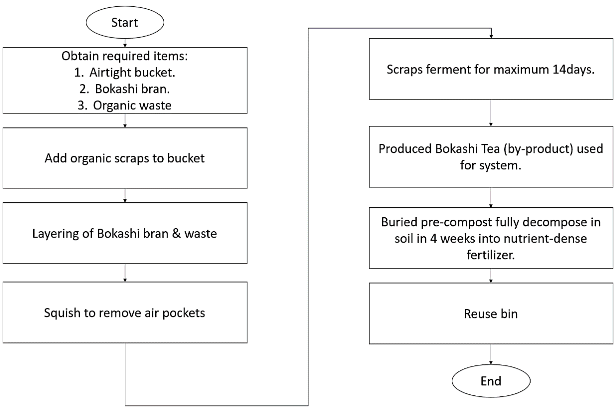


Figure 1. Bokashi Composting Procedures

To utilize the fertilizer yields from Bokashi composting, it must first be produced. Bokashi composting requires three main items which are airtight bucket, Bokashi bran and organic waste. The organic waste needs to be layered with a generous amount of Bokashi bran for every 2 cm of thickness inside of an airtight bin and compressed to eliminate air. Then, the waste is left with the lid on for it to go through anaerobic fermentation catalyzed by the effective microorganisms from Bokashi bran. The waste starts to produce Bokashi Tea, a fermentation by-product that is used for this project as fertilizer. Production of Bokashi Tea is continued up to 2 weeks, after which the pre-compost solids need to be buried in soil to fully compost in another 4 weeks. The choice of a 2 weeks composting period was based on achieving complete fermentation of organic waste, ensuring maximum nutrient extraction and stability in the Bokashi Tea. Although the cumulative volume of Bokashi Tea stabilizes after 8 days, extending to 2 weeks allows for consistent processing of various waste types and ensures thorough decomposition, avoiding premature cessation that might affect compost quality [7].

Three batches of experiments were done to investigate and verify the information obtained from previous research [1] and to further confirm whether Bokashi composting is suitable for residential homes application, hence its relevance for the Bokashi-Based Home Composter for Fertigation System.

### 2.2 System Architecture

The microcontroller used to operate the system is the ESP32 due to its convenience to program using the Arduino IDE. Figure 2 is the system architecture showing the devices and components used for the system to function as a control box.

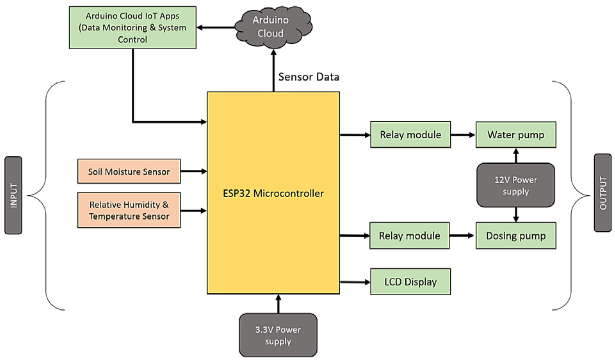


Figure 2. System Architecture

The system uses inputs from soil moisture sensor and relative humidity and temperature sensor, with 3.3V supply. These sensors data are used according to the programming while simultaneously being fed to the cloud storage for IoT implementation using Arduino IoT Cloud. Then, the system response signals through LCD display and two relay modules connected to two pumps that functions as main pump and dosing pump respectively which are supplied by 12V sources.

Figure 3 shows the system sketching. The control box supplies signal to the relays connected to dosing pump and main pump. The dosing pump inlet is connected to the bottom of the Bokashi bin and outlet connected to the water container. The main pump on the other hand supplies contents from the water container to the plants. The system parameters are also available for monitoring and control through an application designed with Arduino IoT Cloud.

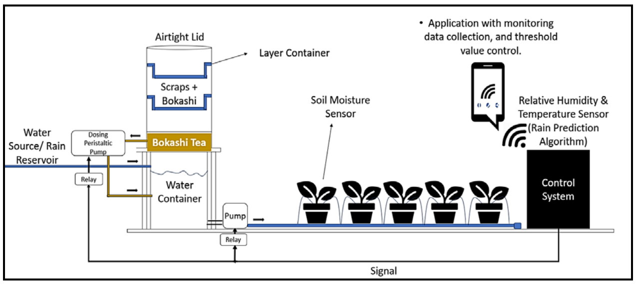


Figure 3. System Sketch

Next, in terms of the system workflow, it is shown in Figure 4. Produced Bokashi Tea from Bokashi composting accumulates at the bottom of the bin. User have the option to mix it with the water through dosing pump and use it as fertilizer for the system or leave it unused. If user decides to dose Bokashi Tea into the water container, it can be done through application-controlled button which doses according to the time left on. At any time during the system activation, the system has a rain prediction system which decides rain at above 85% relative humidity and temperature below 30°C. This simple algorithm is used to avoid resource redundancy with the rain water. Otherwise, if the system predicts that there is no rain, it will wait for sensor input and pumps the contents of the water container to plants if it detects soil moisture parameter is under the set threshold. The threshold is adjustable through the application. The application also receives data from the system in real-time and displays the input sensor readings in the form of meter and graph over time, pump status, pump trigger level and the dosing control button. The system and application works together as an IoT and requires Wi-Fi connectivity to function.

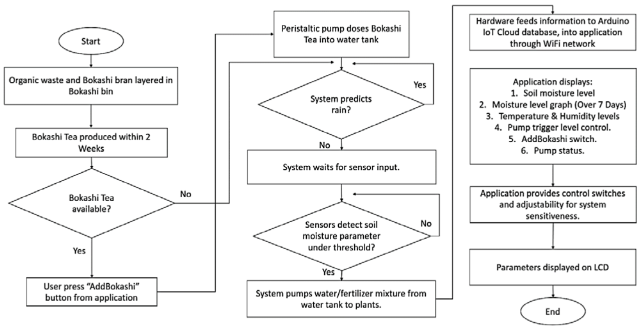


Figure 4. System workflow

The results and discussion are separated into three parts, which includes Bokashi composting, Hardware configuration and Application Dashboard to determine the system performance.

## 3. RESULTS AND DISCUSSION

### 3.1 Bokashi Composting

Figure 5 shows the condition of Bokashi Composting after 3 days of composting while Figure 6 shows the condition of the compost after 14 days. Based on the experiments done with 500g of Guava, the yield Bokashi Tea shows promising results but with certain drawbacks. Some errors were also discovered during the experiment, which led to bad and smelly yield as seen in Figure 7. Otherwise, when the composting is done properly, the yield qualitative and quantitative results was as good as expected.

Figure 5. Bokashi Composting After 3 Days

Figure 6. Bokashi Composting After 14 Days

Figure 7. Bad Yield from Bokashi Composting

Table 1 shows the yield obtained from three batches of experiments, while Table 2 shows data analysis of Bokashi composting experiments.

Table 1. Bokashi Experiment Yield

| Day | Batch Volume (ml) | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| 1 | 0 | 0 | 0 |
| 2 | 10 | 10 | 10 |
| 3 | 30 | 30 | 25 |
| 4 | 40 | 50 | 50 |
| 5 | 50 | 70 | 65 |
| 6 | 65 | 95 | 90 |
| 7 | 75 | 115 | 110 |
| 8 | 80 | 125 | 120 |
| 9 | 80 | 125 | 120 |
| 10 | 80 | 125 | 120 |
| 11 | 80 | 125 | 120 |
| 12 | 80 | 125 | 120 |
| 13 | 80 | 125 | 120 |
| 14 | 80 | 125 | 120 |

Table 2 is referred on the experiments done to obtain data for Bokashi composting. 3 batches of experiments were executed, each using 500g of guava waste. The quantitative and qualitative parameters are observed. For the first batch, the experiment was a failure, where the Bokashi compost turned out bad and smelly, while producing a cumulative volume of only 80ml of Bokashi Tea on the 8th day and onwards. The expected Bokashi Tea yield is supposed to only have slight pickle-like smell, which is different from the expectations based on the research [6] done on Bokashi composting method. It was later determined that the cause of failure was the pressure buildup inside the Bokashi bin which causes the lid to slightly open. This error caused the compost to have constant supply of oxygen, when Bokashi composting is supposed to be anaerobic process, hence causing the compost pile to turn bad.

Table 2. Data Analysis of Bokashi Composting

| BOKASHI YIELD | | | |
|---|---|---|---|
| Batch No | Qualitative | Quantitative | Duration (Days) |
| 1 | Fruity smell<br>Newly formed white mold<br>Slight discoloration of waste<br>Waste structure still similar to fresh waste | Original Weight: 500g<br>Volume: 30ml | 1 to 3 |
| | Slightly unpleasant smell & white mold<br>Extreme discoloration of waste<br>Waste does not keep its structure due to loss of moisture<br>Pressure buildup and moisture | **Volume: 80ml** | 7 to 14 |
| 2 | Fruity smell<br>Newly formed white mold<br>Slight discoloration of waste<br>Waste structure still similar to fresh waste | Weight: 500g<br>Volume: 30ml | 1 to 3 |
| | Pickle smell & white mold<br>Discoloration of waste<br>Waste does not keep its structure due to loss of moisture<br>Moisture around bin sides | **Volume: 125ml** | 7 to 14 |
| 3 | Fruity smell<br>Newly formed white mold<br>Slight discoloration of waste<br>Waste structure still similar to fresh waste | Weight: 500g<br>Volume: 25ml | 1 to 3 |
| | Pickle smell & white mold<br>Discoloration of waste<br>Waste does not keep its structure due to loss of moisture<br>Moisture around bin sides | **Volume: 120ml** | 7 to 14 |

Thus, the correct cause of action to avoid the problem from happening is for users to keep the lid closed during composting, but open it briefly once a day to release pressure and prevent accidental opening. However, this problem should not occur to regular users as organic waste are layered every day until the bin is full. Users are only limited to fill in the waste at the end of the day to avoid the probability that too much oxygen is supplied which may lead to bad yield.

For the next two batches however, the yields are pretty consistent where 25 ml to 30 ml of Bokashi Tea is produced after the third day, and the maximum cumulative volume is 120 ml to 125 ml. These batches turned out as expected and showed promising symptom with the Effective Microorganisms (EM) being active. The production of Bokashi Tea can also be considered a linear function, where it produces approximately the same amount of yield up until day 8.

However, as seen in Figure 8, the cumulative amount of yield produced stayed constant throughout day 8 to day 14, before the pre-compost is matured and ready to be buried in soil. This observation led to the conclusion that 8 days is the limit for guava waste to produce Bokashi Tea. This factor might vary when using different organic waste, where dryer waste would naturally produce less Bokashi Tea while the opposite is true for waste with higher moisture content such as watermelon waste [2].

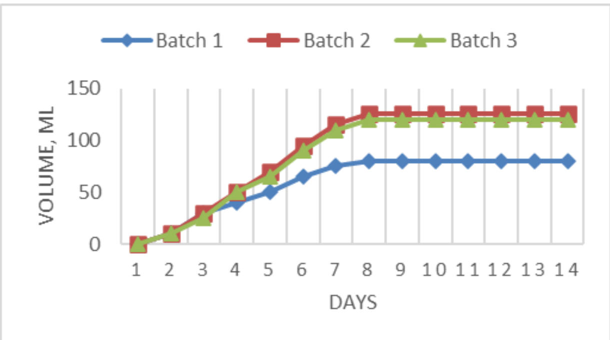


Figure 8. Bokashi Tea Production Trend

### 3.2 Application Dashboard

Figure 9 and 10 show the desktop and mobile dashboard respectively. The system works as long as the control box is connected to the setup Wi-Fi connection, and the application will work no matter if its Wi-Fi connection is the same or different to the one connected to the ESP32. However, response time may vary.

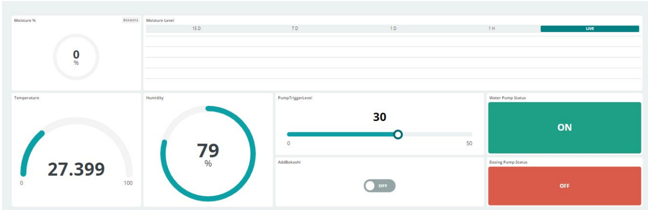


Figure 9. Desktop Dashboard

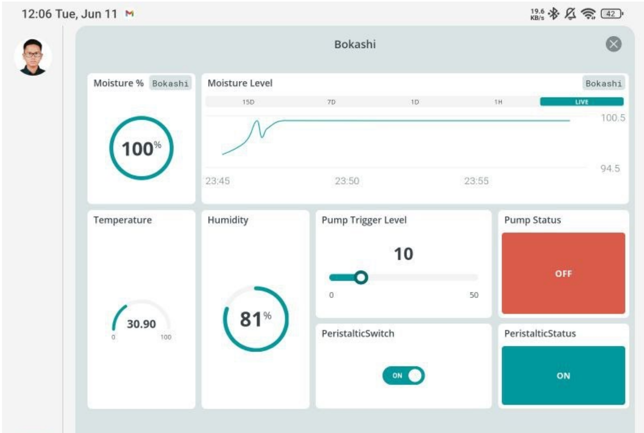


Figure 10. Mobile Dashboard

### 3.3 Hardware Configuration

The system control box is connected as shown in Figure 11. The soil moisture sensor and DHT22 are connected to the input of ESP32, while the outputs of the microcontroller are connected to LCD, and the respective relays that controls the operation of two 12V DC pump devices. Since ESP32 can only supply up to 3.3V, it cannot directly power up the pumps, therefore external voltage source is supplied through 5V and 12V. The components are soldered on to a donut board to ensure stable connection and improve system consistency.

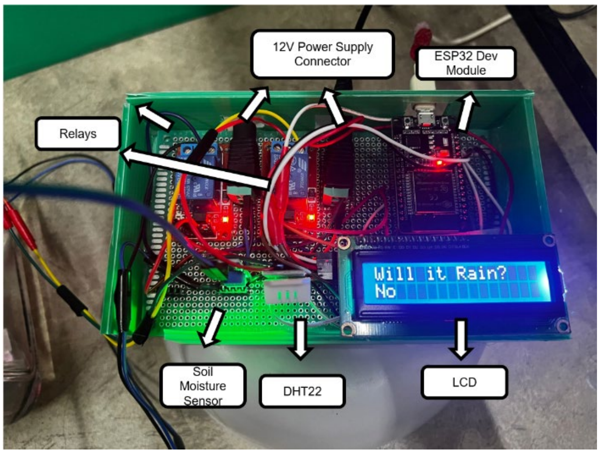


Figure 11. System Control Box

Figure 12 shows the overall system configuration, where the control box is connected to the water pump and dosing pump. The tubes from Bokashi bin are connected to the dosing pump to supply Bokashi Tea to water tank, and the water pump will fertigate into vase depending on the inputs obtained from the system parameters. The system performance and flow rate are analyzed and discussed.

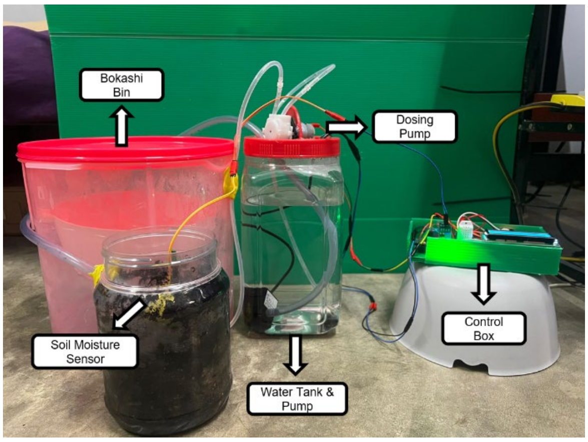


Figure 12. System Configuration

Table 3 and 4 show the water pump and peristaltic pump flow rate and system response time respectively while Figure 13 and Figure 14 show the flow rate in 10 iterations.

Table 3. Water Pump Flow Rate & System Response Time

| PUMP | | | | | |
|---|---|---|---|---|---|
| No | Volume (ml) | Time (s) | Flow rate (ml/s) | Response Time (s) | |
| | | | | OFF to ON | ON to OFF |
| 1 | 900.00 | 29.28 | 30.74 | 6.68 | 8.49 |
| 2 | 1175.00 | 41.06 | 28.62 | 9.63 | 6.17 |
| 3 | 1020.00 | 30.95 | 32.96 | 7.87 | 8.33 |
| 4 | 1350.00 | 39.74 | 33.97 | 8.33 | 5.95 |
| 5 | 950.00 | 31.25 | 30.40 | 8.12 | 7.36 |
| 6 | 1305.00 | 40.60 | 32.14 | 7.31 | 6.69 |
| 7 | 1065.00 | 30.69 | 34.70 | 7.55 | 7.85 |
| 8 | 1380.00 | 39.87 | 34.61 | 8.63 | 8.16 |
| 9 | 1000.00 | 30.50 | 32.79 | 7.01 | 7.56 |
| 10 | 1360.00 | 40.57 | 33.52 | 7.23 | 7.11 |
| Average | | | 32.45 | 7.84 | 7.37 |

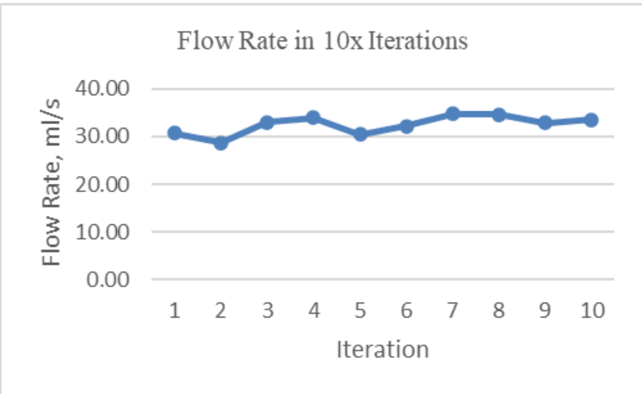


Figure 13. Water Pump Flow Rate

Table 4. Dosing Pump Flow Rate & Response Time

| PERISTALTIC PUMP | | | | | |
|---|---|---|---|---|---|
| No | Bokashi Tea (ml) | Time (s) | Flow rate (ml/s) | Response Time (s) | |
| | | | | OFF to ON | ON to OFF |
| 1 | 100.00 | 60.19 | 1.66 | 6.76 | 8.67 |
| 2 | 110.00 | 67.80 | 1.62 | 7.87 | 9.65 |
| 3 | 110.00 | 70.96 | 1.55 | 9.60 | 7.85 |
| 4 | 90.00 | 61.66 | 1.46 | 7.67 | 2.61 |
| 5 | 120.00 | 70.86 | 1.69 | 3.65 | 1.58 |
| 6 | 95.00 | 70.95 | 1.34 | 4.12 | 9.12 |
| 7 | 95.00 | 61.14 | 1.55 | 10.38 | 10.51 |
| 8 | 110.00 | 70.84 | 1.55 | 1.68 | 2.75 |
| 9 | 120.00 | 70.91 | 1.69 | 2.91 | 4.15 |
| 10 | 110.00 | 70.54 | 1.56 | 3.16 | 7.96 |
| Average | | | 1.57 | 5.78 | 6.49 |

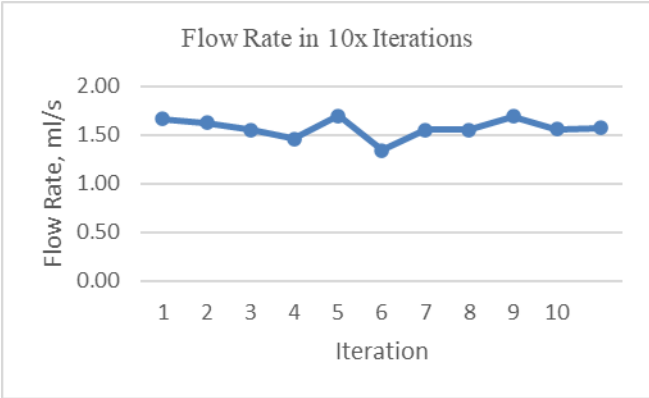


Figure 14. Dosing Pump Flow Rate

In order to obtain these data, experiments were done in 10 iterations by filling up a measuring cup over a certain period of time. Then, the flow rate is calculated with the formula shown in Equation 1.

$$\text{Flow Rate} = \frac{\textbf{\textit{Volume (ml)}}}{\textbf{\textit{Time (s)}}} \tag{1}$$

The system response time on the other hand was recorded by taking the time for the system relay to transition from OFF to ON and vice versa after receiving change in parameter values.

The flow rate of water pump is 32.45 ml/s while the flow rate of peristaltic pump is 1.57 ml/s. In order for a plant to be healthy, the average soil moisture requirement is 40% moisture level. Therefore, for 1kg of soil, 400 ml of water is required to set it to 40% moisture level since density of water is 1 $g/ml^3$ . Based on the flow rate average obtained from the data tabulation, increase from 0% to 40% moisture in this setting takes approximately 12 seconds. However, in more practical scenario, the soil moisture only falls to slightly under the pump trigger threshold, thus the dripping occurs in a shorter amount of time. The data has the standard deviation of 1.99 ml/s and 0.11 ml/s for pump and peristaltic pump respectively. Since each iteration shows that data obtained are within the standard deviation, the actual flow rate is accurate [8].

As for the peristaltic dosing pump, the experimental flow rate is 1.57 ml/s. For Bokashi Tea usage, a ratio of 1 to 100 (Bokashi Tea to water) is the optimum recommended usage. Therefore, for every 1000 ml of water, 6 seconds are required for the pump to dose 10ml of Bokashi Tea from bokashi bin. In the system prototype setting, a 3500 ml container is used thus requiring 35ml of Bokashi Tea, which takes 23 seconds to fully pump into the water tank. Table 5 is a guide for users to follow whenever they are adding Bokashi Tea to the water container.

Table 5. Bokashi Experiment Yield

| Bokashi Tea, ml | Water, ml | Time, s |
|---|---|---|
| 10 | 1000 | 6 |
| 20 | 2000 | 12 |
| 30 | 3000 | 18 |
| 40 | 4000 | 24 |
| 50 | 5000 | 30 |
| 60 | 6000 | 36 |
| 70 | 7000 | 42 |
| 80 | 8000 | 48 |
| 90 | 9000 | 54 |
| 100 | 10,000 | 60 |

Since the dosing is controlled by application button by IoT, the system is extremely flexible for users to use a water container of any volume to fulfil their requirement of number of plants they want to benefit the system for. The only major takeaway is that 1:100 ratio is the optimum ratio, where it takes approximately 6 seconds of dosing per 1 Liter of water.

As for the system response time for transition from OFF to ON and vice versa, the system is pretty dependent on the internet connection. Throughout the multiple iterations taken, the results fluctuates and quite inconsistent, however the average system response time is approximately 5.78s to 7.84s. The system definitely benefits from having the same connection as the device controlling the applications, where response time can go as low as 1.58s. Therefore, it is recommended to use the system within the same Wi-Fi connectivity.

## 4. CONCLUSION

In conclusion, the research conducted has led to the successful development of the Bokashi-Based Home Composter for Fertigation System. The system successfully meets its objectives of optimizing resource usage by providing accurate sensor data for fertigation operation. It successfully integrated the process of Bokashi composting to produce fertilizer yield which are automatically used for houseplants in residential homes through IoT implementation. Hence, it ultimately contributes to reducing the organic waste released from residential homes to landfills.

## ACKNOWLEDGEMENT

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