Biogas Generation during Anaerobic Composting of Organic Waste

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Abstract. The amount of solid waste in Indonesia is increasing gradually, with the final treatment facility in the Jatibarang Landfill. One of simple method to reduce the waste quantity is composting. This study used two types of waste, which are leaf waste and food waste, in the composting process. Anaerobic process was chosen to maximize the potential of biogas generation. The anaerobic composting was conducted in duplicate to lower the deviation standard of the study. All of the parameters experienced its peak in day 14, which was in thermophilic condition. The temperature was greater than 55°C, with leaf waste reached 56.22°C while food waste 58.78°C. The moisture content in day 14 was in the lowest condition, lower than 50% in both reactors but the composting process in leaf waste was generally happened in <50% moisture content. Meanwhile, the pH value of both reactors were still ranged the optimum content (6 – 8). The methane gas that has been obtained in this study was greater in food waste than leaf waste. Food waste generated 52.54 µg/m³ of methane gas while leaf waste produced 48.19 µg/m³. However, the impurities of methane gas can be investigated further to identify the best heat value of biogas.

1. Introduction

Solid waste in Indonesia is generated continuously, which surpass the amount of waste that can be managed [1]. The increasing number of population and economic activity is the biggest factor. The waste will be transported into the final disposal facility in Semarang (Jatibarang Landfill). Total of 4,000 m³ waste can be accumulated in the landfill each day, which mainly consist of organic waste (61.95%) [2]. The high composition of organic waste emerges various environmental problems [3]. The degradation of organic compound will produce methane gas, which contributes 23 times greater than CO₂ to the global warming, potentially for centuries [4]. However, if methane gas treated properly, it will have economic value as a renewable energy that can substitute fossil fuel, resulting to the reduction of greenhouse gases emission.

Composting process is an alternative technology to reduce organic waste that enter the landfill and recover methane gas. Composting provides microorganism that can manage waste with high organic compound [5]. This process can convert the waste into useful products, such as compost, which can be an economic fertilizer, and biogas for generating electricity or biofuel [6]. Open windrow is the most common composting method in Indonesia. However, the recovery of biogas would be hard to be conducted because it needs more improvement to accommodate the biogas collection. In-vessel composting can be applied because gas collection pipe can be inserted in the top of the chamber.
Considering the amount of biogas generation, food waste has been proven to have excellent potential, which produce 100 – 200 m³ biogas for one ton food waste [7].

Composting mostly passes through 4 phases before it is complete. The first phase is mesophilic, where the bacteria consumes easily degradable organic and the temperature ranged between 25 – 40°C. After the temperature increases above 40°C, thermophilic phase occurs, which makes mesophilic bacteria deceased and thermophilic bacteria, such as *Actinobacteria*, grows. In the end of the cycle (maturation phase), the temperature will drop and mesophilic bacteria can be reintroduced [8]. However, careful attention is needed to maintain the performance of composting process. Optimum moisture content, pH value, and C/N ratio should be provided to create proper condition for the bacteria [9]. In this condition, biodegradation process can be enhanced and the product can be improved.

This study was conducted to examine the potential of biogas that can be generated from organic solid waste in Jatibarang Landfill. Leaf waste and food waste will be used because it is the major compound of organic waste in the landfill. The concentration of methane during the study was measured. Besides, several parameters, such as temperature, pH value, and moisture content also determined to analyze the performance of anaerobic composting. The composting process is aimed to reduce the managed solid waste, which can increase the capacity of the landfill.

2. Methodology

Four reactors were built to conduct this study. The reactors were column-shaped PVC reactors with 10 cm diameter and 50 cm height. On the top of the reactor, two holes were made as the biogas sampling at one hole and composting parameters sampling (temperature, pH value, and moisture content) at the other. Leachate collection pipe was equipped into the bottom of the reactor. Polyethylene and stretch film were used as the liner of the reactor to prevent any leakage of gas and leachate. Iron crates and plastic mixture was inserted to the lid of the reactor in order to keep any disturbance of air from the outside. Before using the reactor, air and water permeability test was conducted to every reactor by putting cube ice in the reactor, which was used as an indicator of the presence of exothermic or endothermic process. In each reactor, leaf waste (A) and food waste (B) were given with the volume of 14 m³. The waste filled about 45 cm of the reactor and there were 5 cm empty space as the freeboard. The anaerobic composting of each waste was conducted in duplicate to ensure better data of biogas generation and stable degradation process.

This study took place in Environmental Engineering Laboratory for 35 days. The leaf waste and food waste were collected from Jatibarang Landfill. Temperature, pH value, and moisture content were measured every 7 days to monitor the performance of composting process each week. Temperature measurement was conducted by using thermometer while moisture content and pH value using pH moisture meter. On the other hand, the samples to determine methane gas concentration were collected using 10 mL syringe BD and stored in vacuumed vials. The taken samples were sent to Greenhouse Gases Laboratory in Balai Penelitian Lingkungan Pertanian, which used Gas Chromatography.

3. Results and discussions

3.1. Moisture content

Moisture content is an important factor that determines the properties of compost. In optimal condition, which is ranged in 50 – 60%, biodegradation process will occur efficiently because the microbial activity is enhanced [10]. Figure 1 showed the fluctuations of moisture content in the anaerobic composting process during 35 days. Initial moisture content in each reactor was 45.8% (reactor A) and 50.3% (reactor B), which was originated from the existing moisture content of both waste in landfill. Both reactors experienced a rise in 7 days, which reach 45.8% for reactor A and 51.8% for reactor B. The moisture content of reactor A and B started to decrease until day 14, which was 47.5% and 43.2% respectively. This condition indicated that the microbial activity was in peak
condition, causing evaporation of water in the waste. After reaching its peak condition, the moisture content began to increase, indicating the metabolism activity of the microbes became slower and condensation of water occurred faster than the evaporation process. The rise of moisture content happened until the end of the study. Reactor A, which was filled with food waste, had better initial moisture content than reactor B (leaf waste). Reactor A provided the optimum moisture content that made the activity of bacteria enhanced better.

![Figure 1. Profiles of moisture content in the composting process](image)

### 3.2. Temperature
Temperature is a factor that indicates the process of microbial activity and the types of bacteria that grow and develop during the composting process. It also affects the greenhouse gas emissions [10]. High temperature in composting process has the advantage to reduce the pathogen [11]. The changes of temperature in this study are shown in figure 2. The temperature in day 0 started in room temperature, which was about 28°C. The mesophilic bacteria grew until 7 days with the indication of the rise of temperature in reactor A and B, which reached 46.61°C and 49.53°C respectively. The temperature continued to increase in the second week and reached the peak temperature in day 14 that also caused the decrease of moisture content. In this state, the metabolism of the bacteria rapidly occurred. The thermophilic bacteria dominated this phase because the temperature reached 56.22°C for reactor A and 58.78°C for reactor B. After the thermophilic phase occurred, the temperature dropped until it entered mesophilic phase in day 21, where the temperature decreased in around 40°C for both reactors. The temperature still fell until it achieved the room temperature in day 35, which also indicated this study ended in the same day. The temperature in food waste was always higher than leaf waste. It was because the higher content of moisture in food waste made the condition for bacterial activity becomes better.

![Figure 2. Changes of temperature](image)

### 3.3. pH value
The important factor that affects the quality of compost produced beside moisture content is pH value. The optimum condition can be achieved in pH value around 6 – 8. Moreover, lower value in pH leads to the inhibition of microbial development the reduction of degradation rate [12]. Meanwhile, higher pH value that is still in optimum range will increase the length of thermophilic phase and the quality of the compost. Reactor A and B had pH value of 7.2 and 7.4 respectively in day 0. The optimum value had been achieved since the study began, which ensured that the composting process can be initiated. The value of pH was increasing in day 7, with the amount of 7.3 for reactor A and 7.6 for reactor B. It gradually rose until reaching its peak in day 14. Reactor A had pH value of 7.5 while reactor B 8.0.
These values are the range of pH in thermophilic phase, which also signified with high temperature (>50°C) in the same day. The pH value began to drop along with the change of phase into cooling phase and maturation, which the biodegradation rate also decreased.

![Figure 2. Changes in temperature in the compost](image)

3.4. Methane gas
The generation of methane gas experienced rise and fall during this study, which is shown in figure 4. The changes were in correspondent with the pattern of other parameters (moisture content, temperature, and pH value). It was because the metabolism process of methanogen bacteria in anaerobic condition produced methane gas [10]. In the first 24 hours, the methane gas for both reactors was measured in the value of 6.80 µg/m³ (A) and 7.10 µg/m³ (B), which illustrated in day 0. It rose until it exceeded 10 µg/m³ in 7 days. The increment of methane gas remained until it reached its peak in day 14 for reactor A and B, which were 48.19 µg/m³ and 52.54 µg/m³ respectively. The methane gas became decreased after thermophilic phase finished in day 21, with the concentration of 41.64 µg/m³ for reactor A and 45.44 µg/m³ for reactor B. It gradually dropped until 35 days of the study as the bacterial activity decreased. The profile of methane gas that produced in this study is coherent with
Jiang [11]. Food waste had better methane gas composition than leaf waste but the difference was not significant. However, leaf waste is the major component of organic waste in Semarang. Hence, it held great potential to produce methane gas to be recovered as an alternative energy.

![Figure 4. Fluctuations of methane gas generation](image)

4. Conclusion
The mesophilic phase happened during the first seven days of the study. The thermophilic phase took over after 7 days and achieved the highest temperature in day 14, which are 56.22°C and 58.78°C for leaf waste and food waste respectively. It also followed by pH value that reached its peak and moisture content that decreased most. Highest pH value was found in food waste (8.0) while lowest moisture content was found in leaf waste (43.2%). Leaf waste had lower moisture content because it was already low since the beginning of the study. The same pattern of changes in these parameters was also found in the methane gas production. The reactors emitted methane gas the most in day 14, where all parameters also reached its optimum. The highest methane gas production was 48.19 µg/m³ for leaf waste and 52.54 µg/m³ for food waste. Both wastes has shown the potential to be the sources of biogas, which can be utilized as alternative energy. The identification of contaminant in the biogas can be explored to increase the total energy that can be produced by the biogas.

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