

Composition of Domestic Solid Waste on Biogas Production and Characteristic in MSW Landfill

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Abstract. Organic solid waste will undergo a decomposition process and produces some gases compounds such as a large enough of Methane (CH₄), Carbon Dioxide (CO₂) with Oxygen (O₂) and N₂. The high heating value of CH₄ in biogas can make biogas as a good source of renewable energy and environmentally friendly. Biogas calorie efficiency is proportional to the concentration of CH₄ in biogas. However, the quantity and quality of biogas that produced in landfill depend on the characteristic and density of domestic solid waste in landfill. The composition of organic and inorganic waste and the density of waste pile will alter the CH₄ content. This study focuses on measuring CH₄ content of the solid waste with different density while also identifying the composition of disposed solid waste. The result indicates that the CH₄ content ranges from 33% to 57.7% with 22.19% to 42.24% of CO₂ and approximately 1.21% - 7.92% of O₂. The presence of inorganic waste and density level of waste contribute to the decomposition rate and CH₄ content.

Keywords: Biogas; solid waste; landfill; methane

1 Introduction

The population in Semarang City is increasing from time to time, reaching 1.7 million people in 2017. Along with the increasing of population and human activity, there will be some environmental problems; one of them is solid waste generation. Solid waste produced by residents of Semarang City reaches 438.000 tons per year with composition approximately of 62% organic waste, and 38% inorganic waste. Solid wastes generated by Semarang's residents are sent to Jatibarang landfill which has been operated since 1993 [1]. The amount of solid waste that goes to Jatibarang landfill is about 950 tons per day, which is about 80% of the total solid waste generated. Sorting of inorganic and organic waste is partially conducted at the landfill. The inorganic waste can be recycled while organic waste that is buried will undergoes a decomposition process in the landfill [2].

Organic waste can be decomposed through aerobically and anaerobically [3]. The by-products of anaerobic decomposition are leachate and biogas. Biogas is produced from anaerobic process of biomass biodegradation in the absence of oxygen and assisted by anaerobic microorganisms [4]. The biogas composition of landfill consists of CH₄ as the main biogas content of 45%, and other contents of CO₂ by 32%, N₂ by 17%, O₂ by 2% and N₂ by 4% [5]. The gas collection pipes in the landfill generally accommodate the entire landfill zone with the characteristics of mixed waste between organic and inorganic in a various density. It leads to the unknown composition of biogas based on certain composition and density of waste. Therefore, this study

aims to analyze the composition of biogas based on the composition and density of solid waste. The result of this study will be useful for the solid waste management authorities to determine the proper method to handling organic solid waste and to support low carbon society.

2 Materials and methods

2.1. The experiment

In this study, test of biogas content in the waste generation was conducted. The experiments were performed using 4 reactors with the dimension of 70x70x100 cm, with the installation of biogas distributors and a gas chamber to collect the biogas (Fig. 1).

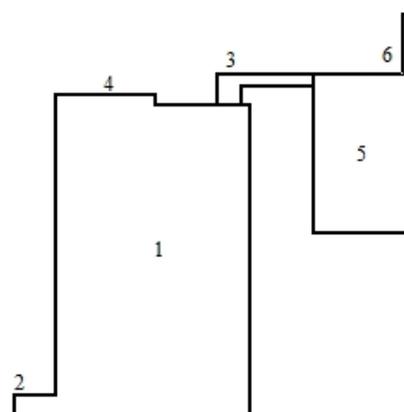


Fig. 1. Biogas Reactor

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Notes:

1. Digester
2. Sludge outlet
3. Gas outlet
4. Inlet
5. Gas chamber
6. Outlet

Subsequently, the all four reactors were given different treatment as follow:

1. The first reactor was labeled as O1, contains 70% of organic solid waste with density of 250 kg/m³.
2. The second reactor was labeled as O2, contains 70% of organic solid waste with density of 400 kg/m³.
3. The third reactor was labeled as A1, contains 40% of organic solid waste with density of 250 kg/m³.
4. The fourth reactor was labeled as A2, contains 40% of organic solid waste with density of 400 kg/m³.

Following different treatments in each reactor, the levels of CH₄, CO₂, O₂, N₂, and temperature was measured. The measurements were performed for 3 months at monthly interval for each parameter. Data analysis was performed as the value is obtained each reactor.

2.2. Solid waste

The MSW is collected from a transfer station at the Banyumanik District, Semarang and sorted by hand. Prior to characterization, the organic wastes were treated separately, dried by natural air, chopped to a size of about 4 mm and kept at room temperature in a container. The composition of solid waste sample is presented in Table 1.

Table 1. Waste characteristic

Composition	Weight (%) Wet
Organic fraction	62.8
Steel	0.2
Glass	1.1
Paper	11.4
Fabrics	0.4
Plastic	22.5
Wood	0.9
Rubber	0.7

3 Results and discussions

According to Fig. 2, there was a decrease in temperature in reactor O1 and in reactor A1 along with the increase of decomposition time. However the decreasing temperature was not significant. In the reactor O1, the temperature decreased from 47°C to 44°C while in the reactor A1, the temperature slightly dropped from 38°C to 35°C. Meanwhile, in reactor O₂, the lowest temperature occurred in the second month, before bounced back in third month. While for reactor A2, the temperature was fluctuating ranging from 42°C to 50°C.

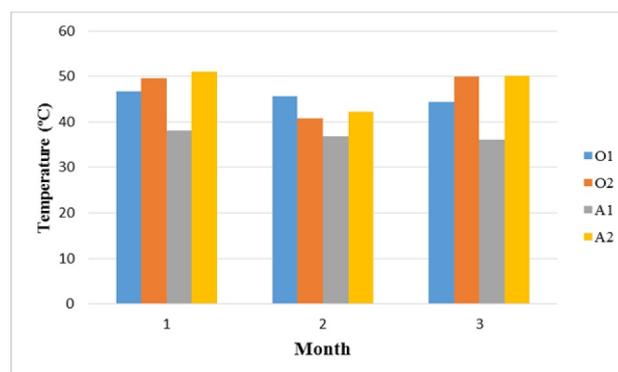


Fig. 2. Temperature inside the digester

The temperature level inside the digester is very important in biogas production process [6]. Anaerobic fermentation process is very sensitive to temperature changes [7]. The temperature for the most optimum anaerobic decomposition at mesophilic phase ranged from 30°C to 40°C while at thermophilic phase the temperature were 50°C to 60°C. The temperature at four reactors ranged from 36.17°C to 51.01°C which fulfilled the criteria of temperature range for the most optimum anaerobic fermentation [8]. The optimum temperature becomes one of the conditions for anaerobic process to occur quickly and produce high amount of biogas with a good quality characterized by high CH₄ gas content [9].

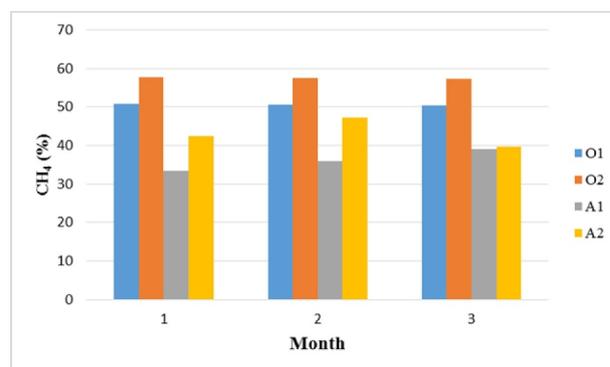


Fig. 3. Level of CH₄ during experiment

Figure 3 shows the percentage of CH₄ in O1, O₂, A1 and A2 reactors during experiment. The results showed small changes throughout the decomposition period. The percentage of CH₄ in the four reactors ranged from 33%

to 57.7%. The percentage of CH₄ in O1 had a tendency to stable during 3 months of decomposition process ranging from 50.42% to 50.75%. The percentage of CH₄ in O2 was also stable during three months in range of 57.24% to 57.62%. Meanwhile, the percentage of CH₄ in A1 tended to have small increment from 1st to 3rd month, while the percentage of CH₄ in A2 tended to fluctuated a little bit from 39.77% to 47.19%.

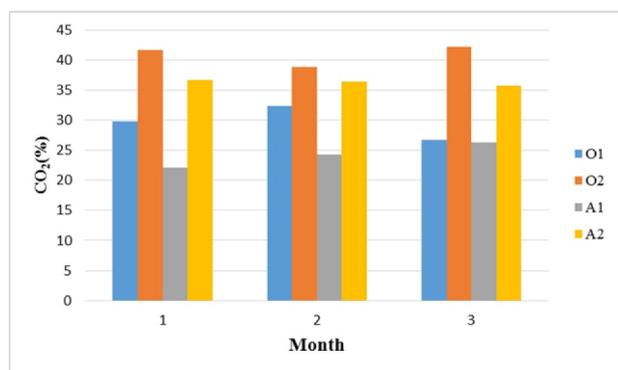


Fig. 4. Level of CO₂ during experiment

Figure 4 depicts the level of CO₂ within three months. The percentage of CO₂ tended to fluctuate in all four reactors, the percentage of CO₂ ranged from 22.19% to 42.248%. The percentage of CO₂ in O1 reached the highest level in the second month, which is 32.43% and decrease to 26.66% in the third month. In the reactor O2, the CO₂ percentage reached 41.75% in the first month, but then decreased to 38.91% in the second month and bounced back to 42.24% in the third month. In A1, there is a slightly increase of CO₂ percentage during three months from 22.19% to 26.33%. While the percentage of CO₂ in A2 tended to be steady, with a range of 35.71% to 36.69%.

According to figure 3 and 4, there was a similar trend of CH₄ and CO₂ level in all reactors over three months observation period. The presence of CO₂ gases in biogas will reduce the content of other gases, especially CH₄ and will reduce the heating value of biogas [7]. The highest level of CH₄ was generated by the reactor O2 that contain 70% of organic fraction with 400 kg/m³ of density.

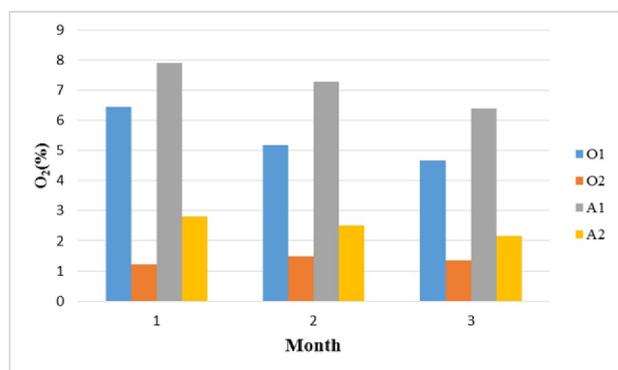


Fig. 5. Level of O₂ during experiment

The percentage of O₂ in all reactors are shown by figure 5. Level of O₂ in reactor O1 decreased with the

increasing time of decomposition, but the value of difference was not significant ranging from 4.68 to 6.46%. Meanwhile, in reactor O2, the level of O₂ during three month of experiment was relatively steady ranging from 1.21% to 1.48%. The percentage of O₂ in reactor A1 indicated a decreasing trend during three months, falling from 7.92% in the first month to 6.4% in the third month.

In reactor A1, the trend of O₂ was decline during the decomposition period from 7.92% to 6.4%. This declining sign was also found in the reactor A2. In the first month, the level of O₂ in the reactor A2 was 2.82% and going down to 2.17% after three month of decomposition process. The higher level of O₂ were found in the reactor O1 and A1 which contained less density of solid waste. The anaerobic digestion process can proceed with the presence of methanogenic and facultative microorganisms that can consume substrate even in the absence of dissolved oxygen (DO) and accelerating the rate of biogas production [10, 11].

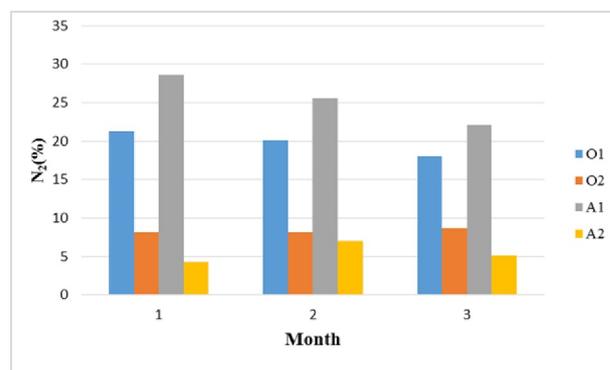


Fig. 6. Level of N₂ during experiment

Figure 6 shows the level of N₂ within three month. The percentage of N₂ in the reactors O1 and A1 indicated a decreasing trend with the increasing time of decomposition. In the reactor O1, the level of N₂ ranged from 18.02% to 21.23% while in the reactor A1 the N₂ value extended from to 22.09% to 28.6%. Meanwhile, the N₂ level of reactor O2 seemed to increase a little bit from 8.16% to 8.86% during three months of observation. By contrast, in the reactor A2, the percentage of N₂ fluctuated from 4.32% in the first month, 6.98% in the second month and 5.12% in the third month.

According to figure 5 and 6, there is a similar trend of the level of O₂ and N₂ in all reactors over three months of observation period. The changes of O₂ level during experiment seem consistent with the level of N₂. The oxygen concentration increases as a result of the existence of heterotrophic denitrification process [12].

4 Conclusions

Biogas generated from decomposition process of solid waste collected in Semarang City contained 33% to 57.7% of methane, 22.19% to 42.24% of carbon dioxide, 1.21% - 7.92% of oxygen, and 4.32% - 28,6% of nitrogen. During the decomposition process, the temperature ranged from 36.17°C to 51.01°C. The amount of organic fraction and the level of density seem to have effect on the biogas production. The highest level of CH₄ is produced by reactor that contain 70% of organic waste with density of 400 kg/m³.

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