Biogas Production from Household Solid Waste – An Alternative Solid Waste Treatment for Communal Scale

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Biogas production from household solid waste– an alternative solid waste treatment for a communal scale

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Abstract. Current practice in Indonesia shows that Household Solid Waste (HSW) is handled by transferring to landfill site. Meanwhile, around 68% of HSW is composed of biodegradable components, which has potential for biogas production. The current study compares some commercial activators including Green Phosko (GP7) and Effective microorganisms 4 (EM4) with homemade activator in 200 L anaerobic digester equipped with manual mixing for processing kitchen waste (KW). pH and ratio of solid waste to water were set at 8 and 1:2, respectively. Batch experiments show that digester #3 with homemade activator shows superior performance compared to commercial activators. Meanwhile, the digesters with commercial activators show better performance compared to digester control (without activator). Digester #3 produces 1.35 L CH_4/kg total solid (TS) and 1.14 L CH_4/kg volatile solid (VS). Current work suggests that the homemade activator has the most suitable methanogen bacterium compared to the commercial activators.

1 Introduction

Current practice in Indonesia shows that Household Solid Waste (HSW) is mostly handled by transferring to the landfill site. Meanwhile, around 68% of HSW is composed of biodegradable components known as organic fraction of municipal solid waste (OFMSW). It is a crucial biomass feedstock, which is potentially recycled into many valuable products. Unfortunately, OFMSW is mainly recycled into fertilizer through aerobic processes in Indonesia. Meanwhile, OFMSW has some characteristics which are suitable as a substrate for the anaerobic digestion process. There are four chemical and biological processes in anaerobic digestion including hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Hydrolysis is a process in which complex organics are degraded into a simple chain such as glucose and amino acids. Acidogenesis is a further degradation for producing volatile fatty acid (VFA), ammonia, carbon dioxide, and hydrogen sulfide [1]. In acetogenesis, acetogen bacterium degrades the simple organic molecules into acetic acid, carbon dioxide and hydrogen [2]. In the last phase, methanogenic bacterium converts intermediate products into methane, carbon dioxide and water with an optimum pH range of 6.5-8 [3]. OFMSW

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may produce biogas of approximately between 300 to 500 m^3 per ton VS depending on its source [4, 5]. In practice, anaerobic digestion may be incorporated into existing municipal solid waste management (MSWM) in which OFMSW is readily available in abundance as a useless component in a landfill, with no extra cost for planting, such as energy crops.

Indonesian Regulation No. 81/2012 states that MSW Treatment must be conducted before landfill. Furthermore, the Ministry of Public Work's Regulation No. 03/PRT/M/2013 says that MSW Treatment includes compaction, composting, material recycling, and waste to energy. However, waste to energy activity is still limited in number in Padang City [6-10]. Most Indonesian cities rely on MSWM for landfilling, which is a primary source of land, river and air pollution. The use of OFMSW for anaerobic digestion process helps reduce the growing environmental problems of current MSWM in Indonesia as well as a dependency on fossil energy. Therefore, the present study focuses on finding an simple digestion process that can be operated by local communities.

2 Methodology

A survey on the composition of biodegradable HSW was conducted to understand the main components of kitchen waste (KW), as listed in Table 1.

Table 1. Composition of biodegradable household solid waste.

Item	Composition (weight %)
Vegetable waste	51
Fruit waste	40
Rice waste	9

Table 2. Experimental condition for each digester.

Item	Condition			
	Digester control	Digester #1	Digester #2	Digester #3
Activator (Variation)	No activator	Green Phosko 7 (GP7)	Effective Microorganism 4 (EM4)	Grown methanogen bacterium in the Substrates
Weight of waste	55 kg			44.89 kg
Ratio of waste to water	1:2			
Weight of water	110 kg			90 kg
Limestone	250 g			320 g
Initial pH of substrate	8			
Manual mixing	3x30 rotation per day			

The composition is used for simulating the substrate's composition for anaerobic digester. Table 2 displays the experimental condition for each digester. The term was varied in four categories based on the activator used, including digester control, digester #1, digester #2, and digester #3. GP 7 and EM4 were chosen as activators in this research due to their market availability. The commercial activators were compared with a homemade activator, which is grown in specific methanogen bacterium in the decomposed KW. The ratio of water to solid waste was kept constant at 1:2. Initial pH of each substrate was also maintained at neutral using limestone. To create optimum contact between the microorganism and the substrates, the same amount of mixing was also applied.

Fig. 1 displays the experimental apparatus. The apparatus was operated in the batch mode in which there was no additional substrate during the trial time. Temperature and biogas volume were recorded every day. Gas chromatography was used to measure methane concentration at the end of the operation.

Fig. 1. Experimental apparatus.

3 Results and discussion

3.1 Biogas production

Fig. 2 displays daily biogas production. Digester #3 shows the highest and the fastest biogas production followed by digester #2. Digester #3 also shows the most top total production of biogas as displayed in Fig. 3. As stated by Wahyuni that activator may accelerate the decomposition process [11], prior acclimatization process on the substrate of digester #3 (decomposed KW) may have grown specific methanogen bacterium. Therefore, digester #3 has the most suitable methanogen bacterium compared to GP7 and EM4. Figure 3 also displays the duration for biogas production. Digester control, #1, and #3 show the period around 17 days, while digester #2 is around 21 days. The results suggest the hydraulic retention time (HRT) for each digester, which means the fresh substrate must be supplied.

3.2 Methane concentration

Methane concentration data as displayed in Fig. 4 confirms that digester #3 has the most suitable methanogen bacterium due to the highest methane concentration (16.36 vol%),

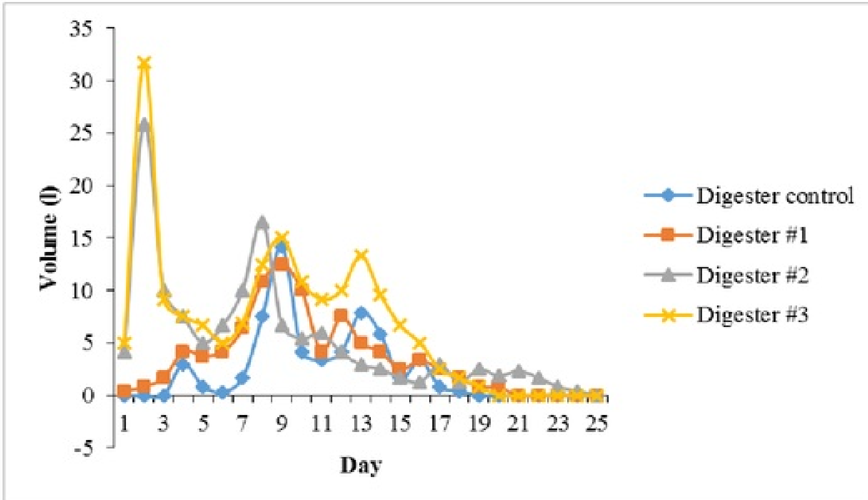

Fig. 2. Daily biogas production.

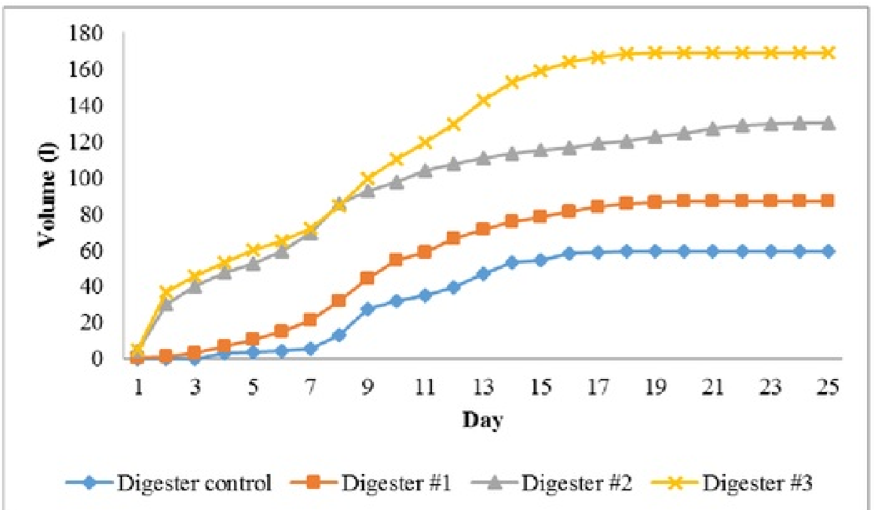

Fig. 3. Total biogas production.

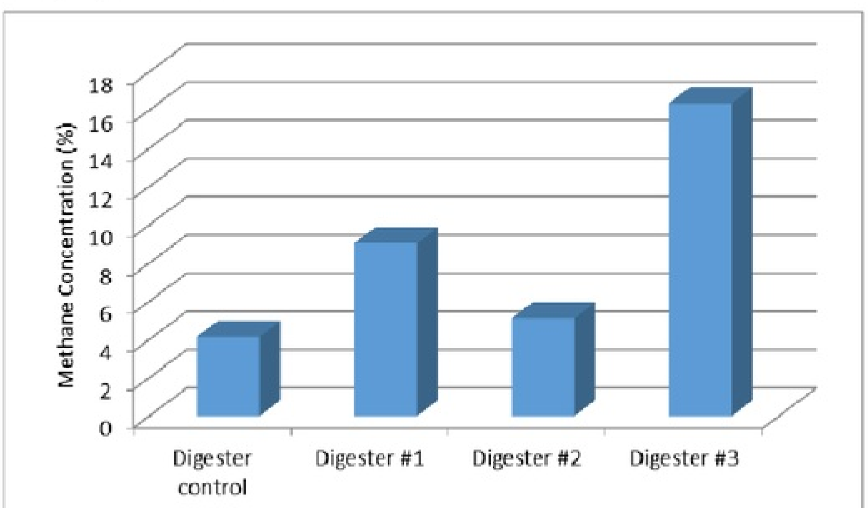

Fig. 4. Methane concentration.

followed by digester #1 (9.03 vol%). Meanwhile, digester #2 shows lower methane concentration since EM4 is not specified for the anaerobic process, but also an aerobic process. However, their concentrations are considered relatively low. Previous researchers observed that co-digested KW with other substrates, such as cow manure, sewage sludge results in a higher degradation rate compared to KW alone [12-14]. Spices contained in KW may inhibit the degradation process of KW as suggested by previous researchers [15, 16].

3.3 Digester comparison

Table 3 lists the performance data of each digester. It was evident that digester #3 shows superiority, producing methane volume per TS and VS at around 1.35 L/kg and 1.14 L/kg, respectively.

Table 3. Digester comparison.

Parameter	Digester control	Digester #1	Digester #2	Digester #3
Total biogas volume (L)	59.20	87.20	130.00	169.20
Methane concentration (Vol %)	4.15	9.03	5.11	16.36
Methane volume (L)	2.46	7.88	6.64	27.68
Total solid (TS) of substrate (kg)*	25.03	25.03	25.03	20.42
Volatile solid (VS) of substrate **(kg)	29.7	29.7	29.7	24.24
Methane volume/TS (L/kg)	0.10	0.31	0.26	1.35
Methane volume /VS) (L/kg)	0.08	0.27	0.22	1.14

*Moisture content of OFMSW in Padang: 45.5 weight% [17], **Volatile content of OFMSW in Padang: 54.0 weight% [17].

4 Conclusions

Specific methanogen bacterium which was acclimated in the substrate shows the superiority performance in producing methane compared to commercial activators. The homemade activator generates around 1.35 L CH_4/kg TS and 1.14 CH_4/L VS. However, the current concentrations of methane are considered relatively low due to the single substrate (KW only) and the inhibitor content (spices).

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