Effectiveness Of Anaerobic Digestion On Reducing Municipal Waste

Budy Rahmat, Rudi Priyadi, Purwati Kuswarini

Abstract: The study was aimed to determine the effectiveness of anaerobic digestion on the reduction on municipal waste. The study was carried out using the batch type biogas digester. This study employed the experimental method with the complete randomized design, involving three instruments of digesters A, B and C. The digester A was filled with 300 g of food waste, the digester B was loaded with 200 g of food waste + 100 g of cow dung and the digester C was charged with 300 g of cow dung as the control. Before placing into each digester, each treatment was mixed with water with the ratio of 1:1 to give the slurry. The results showed that food waste was the main component of municipal waste (50.19%). The rests were plastic (32.71), paper/wood (16.37) and metal (0.71%). The highest daily biogas production was achieved at the first five days as the food waste contained organic compounds which could be converted into the biogas. The highest total biogas production during the retention time of 20 day from 8 L of substrate was achieved by the digester B (56.068 cm^3), followed with the digester C (51.431 cm^3) and A (32.433 cm^3). The digester A might reduce the total solid (TS) from 119.100 into 22.500 mg/L during less than 20 d. The digester B might reduce the TS from 135.200 into 18.400 mg/L and the digester C might reduce the TS from 125.000 into 22.400 mg/L.

Index Terms: anaerobic digestion, biogas production, municipal waste, total solid reduce

1. INTRODUCTION

The municipal waste is known as suitable substrate for the biogas digester because it is rich of organic material from 66.7 until 91.67%. The organic waste provides the nutrient for the growth and the metabolism of anaerobic bacteria in producing the biogas [1]. Biogas production from the biogenic wastes has been an alternative source of fuel in most developing and developed countries in the world Biogas is a mixture of colorless and flammable gases obtained from the anaerobic digestion of organic waste materials. Generally, biogas consisted of methane (50-70%), carbon dioxide (30-40%) and hydrogen, nitrogen as well as hydrogen sulphide [2]. The chemistry of digestion process in the production of biogas involving hydrolysis, acidogenesis or acetogenesis and methanogenesis. The biogas technology has been also employed as waste management and environmental pollution control. The agricultural livestock and agroindustrial wastes in the either rural or sub-urban areas contribute to the environmental pollution problems [3,4]. The biogas production from the anaerobic digestion process containing high organic contents is primarily affected by the organic loadings, temperatures, retentions time in the reactors, pH, the contact frequency between the incoming substrate (feed slurry) and the bacterial population [2].

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It was suggested that the organic loading should be 0.5-1.6 kg/m^3/day of volatile solid (VS) for standard rate digester and 1.6-4.8 kg/m^3/day of VS for high rate digester. The previous researches reported that the gas production was linearly correlated with the temperature (25-44 °C) which was the mesophilic temperature range [4]. Furthermore, there was no significant effect of the retention time on biogas production. Laboratory digesters showed that the reduced hydraulic retention time (HRT) from 40 to 20 days did not affect the biogas production. In contrary, in 200 L farm scale digester found that the cattle slurry of higher VS produced higher amount of biogas over the total 66 days of digestion. The optimal pH digestion was between pH of 6.8-7.3. Additionally, the intermediate mixing seemed to be optimal for substrate conversion which helped the digester to distribute the organism in the mixture and to transfer the heat [5;6]. The advantageous of using the biogas reactor system are reducing the greenhouse gas effects, decreasing unpleasant odor, preventing the disease transmission and producing the heat, power (mechanic/electricity) and by-products such as solid and liquid fertilizers. The utilization of wastes as an energy source will be economically competitive. Besides, this method was considered to be environmentally-friendly and sustainable agricultural practices [2,7]. This study was focused on the municipal waste treatment on the mesophilic anaerobic digester to produce the biogas. The municipal waste was collected from the houses.

2. EXPERIMENTAL SECTION

2.1. Materials and tools

Preparation of substrates

The municipal waste was obtained from the temporary garbage collection in Peta Street near the Campus of Universitas Siliwangi, Tasikmalaya. The garbage was manually classified. The food waste was employed as substrate. The classified waste was cut into the size of 1cm^2 before placing into the digester. The cow dung was used as the control on the production of biogas from the food waste.

Fabrication of Digester

Figure 2 showed the diagram of a set of 10 L of batch digester employed in this study. Three digesters were prepared for three treatments.

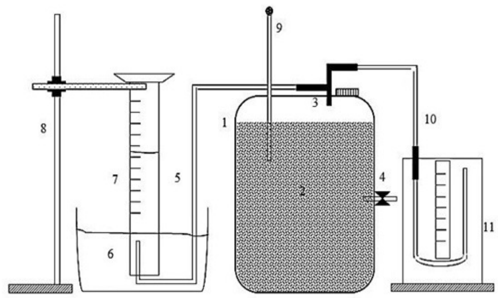

Figure 1. Setup Anaerobic Digester

Descripsion: (1) 10 L Jerrycan as digestion chamber, (2) swaste slurry as a substrate, (3) biogas outlet pipeline, (4) substrate sampling valve, (5) biogas outlet pipeline; (6) water pots reservoir as insulator gas; (7) measuring glass; (8) Statif; (9) thermometer; (10) Biogas flow pipeline to the manometer, and (11) manometer.

Figure 2. Photograph Setup Anaerobic Digester

2.2. Research procedures

This study examined three treatments of biogas substrates: A (food waste), B (food waste+cow dung) and C (cow dung as the control). It was performed using randomized complete design with six replications (24 experiment units) [8]. The study was anaerobically conducted at the mesophilic condition (20- 40 ^{o}C). The digester A was filled with 4 kg of municipal waste and water with the ratio of 1:1. The digester B was loaded with 2 kg of waste and 2 kg of cow dung and the feed was mixed with water with the ratio of 1:1. The digester C was filled with 4 kg of cow dung and water with the ratio of 1:1. The digester was connected with the measuring glass in the reverse position, with the assumption that the amount of water displaced was equal with the volume of the produced biogas. The digesters were placed in the laboratory for the retention time of 20 d. The quantitative response variables were the pH of the substrate which was observed every week, the daily biogas production, accumulation of biogas production during 20 d, the total solid before and after digestion.

3. RESULTS AND DISCUSSION

3.1. Compotition of Municipal Waste

Characterization of the municipal waste samples by sorting and weighing of each component and the results as presented in Table 4. It turns food waste composition occupying the highest (over 50%) in the municipal waste, followed by plastics, and cellulose-based materials such as cardboard and paper. Characterization of municipal waste was carried out by classifying and weighing each component (Table 1). It was found that the food waste was the main component (more than 50%) in the municipal waste, followed with plastic, cellulose-based-materials such as cardboard and paper.

TABLEL 1

COMPOTITION OF MUNICIPAL WASTE

Component	Weight (kg)	Percentage (%)
Food waste	6.75	50.19
Plastics	4.40	32.71
Paper, cardboard and wood	2.20	16.37
Metal	0.10	0.74
Total	13.45	100.00

The condition was interesting to learn by considering that: (i) the food waste had the biggest contribution on the accumulation of the domestic waste volume in level of house, temporary waste collector, and the final waste disposal, (ii) the reduction of waste quantity depended on the decomposition as it was not material which could be recycled; (iii) the decomposition of waste needed a time thus it might lead the environmental pollution. Therefore, the decomposition should be accelerated and produced valuable product, for instance by employing the anaerobic digestion on the biogas digester. On the other hand, the wastes of plastic, paper, and metal could be traded and recycled, thus their accumulation on the environment was relatively not a problem.

3.2. Fluctuation of substrate pH

In the initial digestion time, the pH of the three digesters was significantly decreased (Figure 4). Having passed the hydrolysis process, the acidification (the formation of organic acid, particularly acetic acid) occurred as the activity of acinogen microorganism. Therefore, the pH reduced until the methanogenesis process. Due to several factors, such as the temperature below 20 ^{o}C, the activity of acidinogen bacteria will be increased and that of methanogen bacteria will be inhibited, and the pH might decreased below 5.

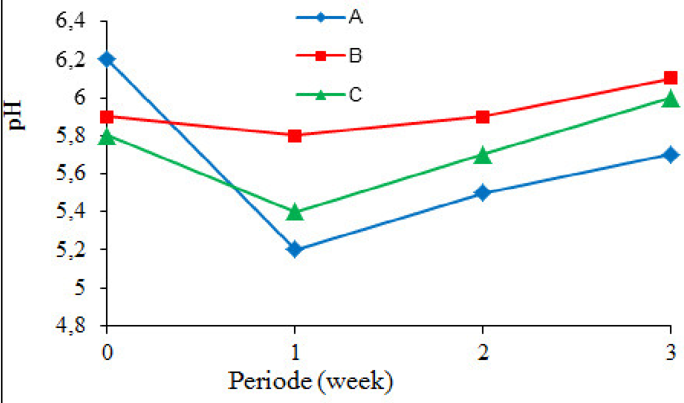

Figure 3. Fluctuation pH of substrate

In the 2nd week, the pH increased as the organic acid was reduced into the carbonate and methane by the activity of methanogen bacteria. The bacteria produced methane via two routes of the fermentation of acetic acid into methane and carbon dioxide and reduced the carbon dioxide into methane using hydrogen gas or formate produced by the other bacteria [9;10].

$$CO_2 + 4\,H_2 \xrightarrow{\text{reduction}} CH_4 + 2\,H_2O$$

Similarly, carbon dioxide might be hydrolyzed into carbonic acid and methane.

$$CO_2 + H_2O \xrightarrow[\text{hydrolisis}]{} H_2CO_3$$

$$H_2CO_3 + 4\,H_2 \xrightarrow{\text{reduction}} CH_4 + 3\,H_2O$$

3.3. Biogas Production

3.3.1. Daily Biogas Production

The daily biogas production on both digester A and B significantly increased as displayed in Figure 3. This was because the food contained the simple organic compound such as sugar, amino acid and fatty acid, which might be fast hydrolyzed and converted into biogas and the other gas [11].

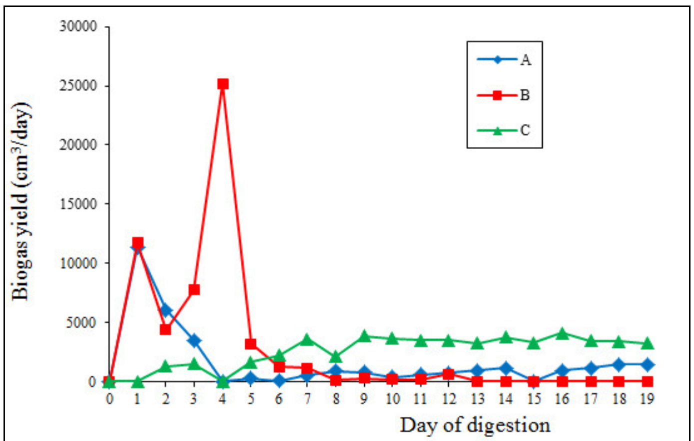

Figure 4. Daily biogas production of digester A, B dan C

It was observed that after 5 days of digestion, the production of biogas approached the zero as the food has almost been digested. On the other hand, the production of biogas on digester C gradually increased after 5 days of digestion and became stable in the range of 3,000-4,000 cm^3 per day. The cow dung mainly consisted of long chain and complex organic compounds, thus it took a longer time for the digestion.

3.3.2. Total Biogas Production

The highest total biogas production per 8 L of processed substrate (Figure 4) during the retention time of 20 days was achieved by the digester B (56,068 cm^3), followed with C (51.431 cm^3) and A (32.433 cm^3). The higher production on the digester B was because it had the substrate with pH and ratio of C/N which were near the optimal value. As explained by Monet [21] the optimum pH for the acidogenesis and methanogenesis was in the range of 6.4-7.2, while the optimal C/N for the anaerobic process was 20-30.

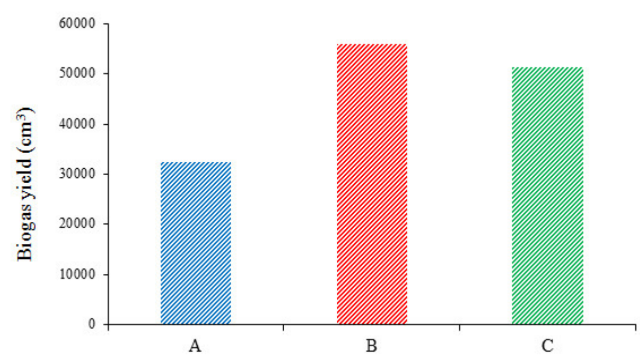

Figure 5. The total volume of biogas produced by the digester A, B, and C for 20 days of retention time

The results of daily and total biogas production showed that the food waste either independently or mixed with cow dung had the potential to generate biogas. This potential should receive more attention as the food waste has not been optimally applied. The high volume of the waste has always been the environmental pollution, such as leaching on the temporary waste collector, odor into the air, and reducing the quality of water, either biologically or chemically.

3.4. Reduction of Total Solids

The decrease of total solid (TS) was considered as the indicator of effectiveness of the anaerobic digestion reaction and the productivity of digester in producing the biogas, as its value was linearly correlated with the produced biogas. It was observed (Figure 5) that the digestion effectiveness in the digester A might reduce the food waste TS from 119,100 into 22,500 mg/L, in the digester B was reduced from 135,200 into 18,400 mg/L and in the digester C was decreased from 125,000 into 22,400 mg/L in the periode less than 20 day.

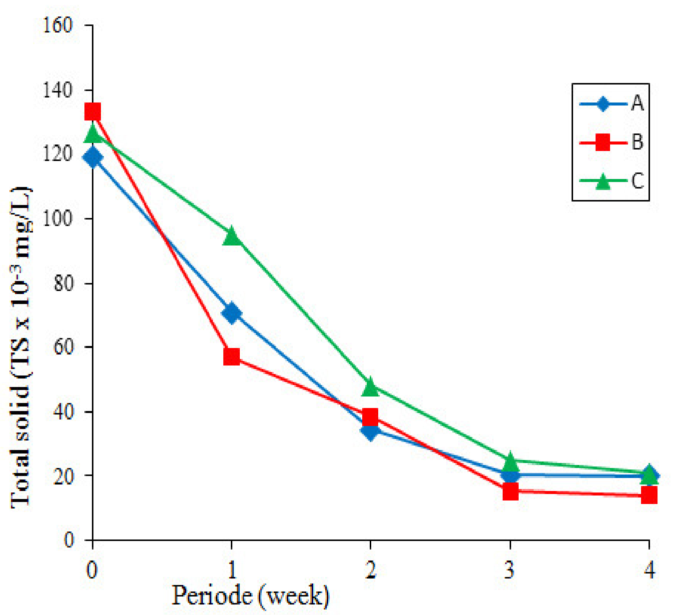

Figure 6. Reduction of total solids in each digester

The effectiveness of anaerobic digestion in producing biogas will be significantly able to reduce the domestic waste. This technology is an important alternative in the treatment of domestic waste in the future, thus the waste accumulation will reduce since the level of household if this technology might be accepted by the stakeholders and implemented into the society.

4. CONCLUSION

Food waste was the largest component of municipal waste (50.19%), and the remaining components were: plastic (32.71%), paper / wood (16.37%), and metals (0.74%). The highest daily biogas production was achieved in the first five days of digestion, because the food waste contained a lot of organic material that easily hydrolyzed and decomposed by microorganisms into methanogenesis material into biogas. The highest total biogas produced in the retention time of 20 day from 8 L of substrate was achieved by digester B (56.068 cm^3), followed with digester C (51.431 cm^3) and A (32.433 cm^3). The digester A might reduce the food waste total solid (TS) from 119,100 into 22,500 mg/L, in the digester B was reduced from 135,200 into 18,400 mg/L and in the digester C was decreased from 125,000 into 22,400 mg/L in the periode less than 20 day.

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