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Printed in the United States of America

Advanced Science Letters
Vol. 4, 1–3, 2012

The Biogas Production from Substrate Mixture of POME and Manure Using CSTR Bioreactor

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ABSTRACT

An integration farming system between cow and oil palm namelly SISKA or the integration of farming cow and energy development (ISSE) has produced the potential of biogas as an energy source and organic fertilizers in large quantities. POME has a high concentration of COD, but the biogas produced was not optimal, so it was important to add manure. Manure contains a lot of methanogenic bacteria, which can increase methane production in anaerobic fermentation process. The purpose of this research was to improve the effectiveness of the conversion of the COD of a mixture of POME and manure into biogas at different rate loading. The results showed that the optimal loading rate was found in the treatment of 1.0 L / day or OLR 0.9956 Kg/m^3/day, which is able to convert COD into methane 0.320 L CH_4 / g COD removal and the highest methane concentration is 60.49%.

Keyword: Biogas, POME, Manure, Methane

1. INTRODUCTION

The government is currently developing an integration system program between cow and oil palm namelly SISKA (Bambang *et al.*, 2012) or the integration of oil plam and energy development called ISSE (Sulaiman *et al.*, 2013). The program is expected to support self-sufficiency in food, energy, and fertilizer. One of the potential energy sources that have not been used optimally is biogas from palm oil mill effluent (POME) and cow dung (manure). The utilization of energy from waste agricultural industry will be able to improve the industry competitiveness (Mel *et al.*, 2015).

The study conducted by Sarono *et al.* (2014) showed that biogas production from POME is not optimal, it is caused the methane gas produced is very small (0.28 L / g COD) and takes a long time. The addition of manure into POME is expected to improve methane produced. A part as a nutrient source of methane-producing, manure is a good source of inoculum for methanogenic microorganisms in the formation of biogas (Saidu *et al.*, 2013). Furthermore, Saidu *et al.* (2013) said that biogas production, with cow manure biostarter, is higher than the use of chicken manure biostater with the highest production of 23.67 grams in the concentration of 15%. On the other hand, the addition of organic co-substrate, to increase the concentration of nitrogen in POME, can keep the balance C/N ratio to increase the production of biogas (Zhang*et et al.*, 2016).

The use of substrate mix is better than using one type of substrate or a single substrate. The mixture consisted of 30% manure and POME 70% which is capable of producing biogas and high COD reduction (Sidik*et et al.*, 2013). Production of biogas, using substrates POME mixture of 1.5 L and manure 500 g, may result in decreased COD, TS and VS with biogas yield higher than the manure substrate with a semi-batch reactor system (Nasir *et al.*, 2012). It is because the manure is rich in methanogenic microorganisms in large quantities (Hong-yan *et al.*, 2015).

By the addition of cow dung as an inoculum, it is expected to increase the production of biogas because it contains a lot of methanogenic bacteria and organic matter. The purpose of this research is to improve the effectiveness of the conversion of the COD of the mixture of POME and manure into biogas in the rate of different loading.

2. EXPERIMENTAL DETAILS

Research was conducted in the Laboratory of Agroindustrial Department of Waste Management, Lampung University. POME and sludge samples were taken from PTPN 7 as the Bekri's Business Unit located

 1936-6612/2012/4/3398/005 doi:10.1166/asl.2012.2049

in Central Lampung and Cow manure was taken from State Polytechnic of Lampung.

The method used is description model by presenting observations in the form of tables and graphs and then analyzed descriptively. The study was conducted in an anaerobic bioreactor *Bench Scale Advance Methan Fermentation; Model AR-50L-3* with a capacity of 50 L which is equipped with a stirrer (CSTR bioreactors) (Figure 1a), gasflow meter types Wet Gas Meter Model W-NK 0:58 (Figure 1.b).

(a) (b)

Figure 1. (a) Anaerobic bioreactors "*Bench Scale Advance Methane Fermentation" (50 L capacity)* ;(b) Gas Flow Meter.

This research was conducted in stages, as can be seen in Figure 2. The study was initiated by determining the characteristics POME, sludge, manure and the mixture POME and manure in the ratio 1:1. The characterizations include the value of pH, chemical oxygen demand (COD), Total Suspended solid (TSS), Volatile Suspended solid (VSS), Total solid (TS), and Volatile solid (VS).

Research carried out by two stages, the acclimatization and biogas production process is conducted with three replications. In the acclimatization phase, the feed of POME was added as much as 0.5 liters and was issued with a total volume loaded. Observations were made of the changes in pH and volume of biogas produced, COD, VSS, TSS, VS, and TS. The acclimatization was conducted up to produce gas with stable pH value.

At the stage of the biogas production process, the treatment used was the rate of loading POME and The manure the mixture, which was added in the bioreactor. The level of on treatment was 0.5 L / day, 1 L / day, 1.5 L / day, 2 L / day 2.5 L / day. The manure solution was made by 1 kg of cow dung added 1.5 liters of water, then the solution was filtered and taken as much as 1.5 liters.

The observation of study were (1) Measurement of biogas production using the wet gas flowmeter meter, (2) Measurement of pH and temperature using a thermometer and a pH meter, (3) Measurement of production TSS and VSSdengan gravimetric method, (4) Measurement of COD using a spectrophotometer HACH DR4000, and (5) biogas composition measurement using Chromathography Gas (GC).

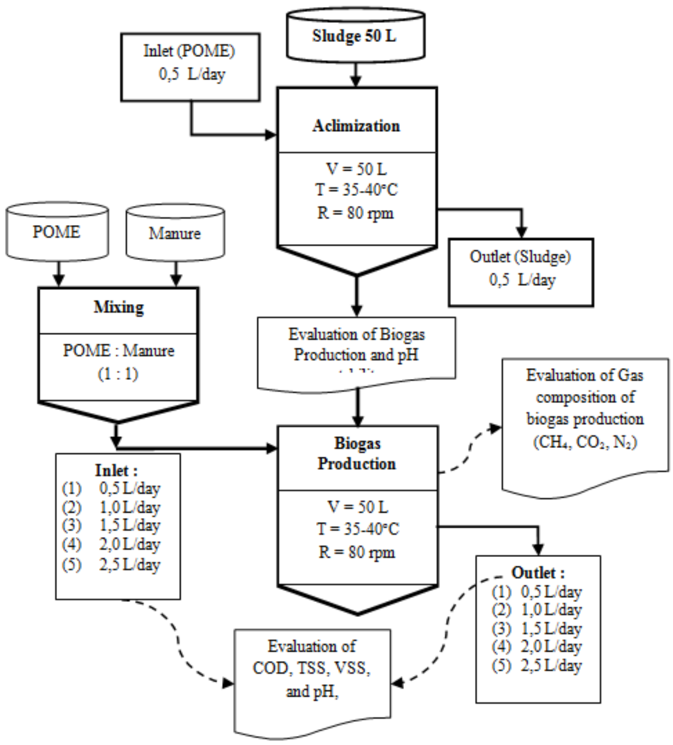

Figure 2. The stages of research implementation

3. RESULTS AND DISCUSSION

A. Acclimatization Phase

The acclimatization process is an adaptation phase of microorganisms to the substrate to be used. The main material used in the acclimatization phase was sludge drawn from an anaerobic wastewater treatment of palm oil. The Substrate added was fresh POME and the characterization of sludge and POME could be seen in Table 1.

Table 1. The characteristics of Sludge and POME

Parameter	Unit	POME Average	Manure Average	The Mixture of POME and Manure (1 : 1)	
				Total	Average
pH	-	5.02	8.02	5.36 – 5.71	5.54
COD	mg/L	60,002	47,137	31,912 – 65,504	50,008
VSS	mg/L	20,748	30,778	17,324 – 26,004	24,232
TSS	mg/L	22,640	37,974	20,540 – 32,426	28,759
TS	mg/L	32,638	43,140	29,470 – 48,780	36,042
VS	mg/L	23,578	35,014	21,670 – 44,130	29,400

Based on the table, it could be understood that the pH value of the sludge is around 7.85. The value has met the optimum pH for growth of methanogenic bacteria. The substrate, with a value of more than pH 7.00 or the substrate neutralized in the initial conditions was a good pH optimum for biogas production (Trisakti *et al*., 2015). VSS content of the sludge is high enough that an average of 4,279 mg / L, so that the bacteria contained in the sludge can produce high methane gas. The VSS and TSS content of the sludge were composed of organic materials and inorganic accumulated in the bioreactor and served as a food source of methanogenic bacteria to produce high methane (Hasanudin *et al*, 2007). In Table 1, it could be seen that the COD value of POME COD was high as 53,714-73,418 mg / L which potentially become serious environmental pollution (Ahmed *et al*., 2015). On the other hand, POME can become potential source of bioenergy (Khemkhao *et al*., 2012).

Inoculum acclimation was held for 18 days and did not require a long time. It is caused by the inoculum used was derived from an existing anaerobic mills and the substrate used was derived from palm oil mill itself, so the bacteria have been used to degrade organic matter derived from palm oil industry. During the acclimatization, the addition and subtraction of bioreactor contents was conducted as much as 0.5 L / day.

The results showed that the pH of the bioreactor was in the range between 7.80 to 7.91. Although the loading on the acclimatization process using substrates with acidic pH value (5.41), the pH conditions in the bioreactor did not decline as seen in Figure 3. According to Hasanuddin *et al.* (2007), the acclimatization is considered sufficient when pH value is relatively constant of about 7 (neutral). The anaerobic microbes, under going acclimatization with proper conditions, will expand and remodel the organic material provided efficiently and produce high biogas.

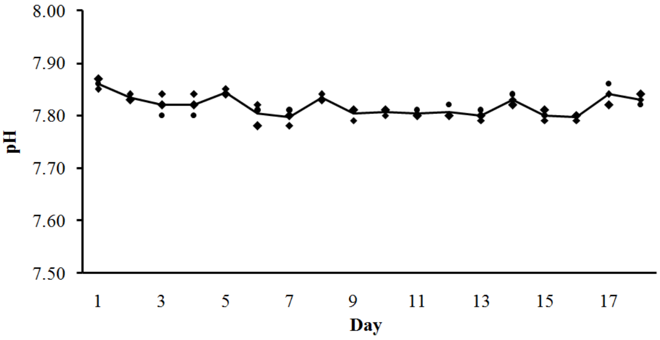

Figure 3. The average of pH value at the acclimatization phase

Furthermore, at the beginning fermentation, biogas volume produced was very small and then increased significantly in the next day, as seen in Figure 4. This was an adaptation phase of microorganisms to the new environment (Khemkhao *et al*., 2012). The figure showed that the production of biogas was beginning to stabilize after day of 8 to 18. The addition of POME substrate into a bioreactor of 0.5 liter / day could produce biogas with an average of 13.96 liters / day / 50 liters.

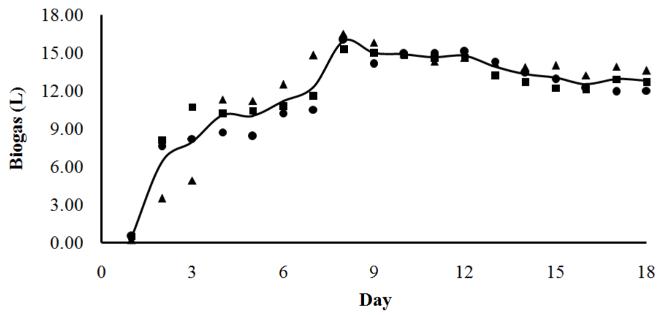

Figure 4. The Average Volume of Biogas Generated during Acclimatization

B. Biogas Production Phase

In the biogas production, the substrate used was the mixture of POME and manure in the ratio of 1: 1. The substrate characterizations were shown in Table 3. In addition to the COD content is high, manure is also very rich in methanogenic microorganisms, such as Bacillus sp., Carnobacterium sp., Psychrobacter sp., Pseudomonas sp., And Clostridium sp. (Hong-yan *et al*., 2015).

Table 3. The characteristic of POME, manure and its mixture with ratio of 1: 1

Parameter		POME Average	Manure Average	The Mixture of POME and Manure (1 : 1)	
				Total	Average
pH	-	5,02	8,02	5,36 – 5,71	5,54
COD	mg/L	60.00	47.13	31.91 – 65.50	50.008
VSS	mg/L	20.74	30.77	17.32 – 26.00	24.232
TSS	mg/L	22.64	37.97	20.54 – 32.42	28.759
TS	mg/L	32.63	43.14	29.47 – 48.78	36.042
VS	mg/L	23.57	35.01	21.67 – 44.13	29.400

(1) COD, COD removal, and Covertion COD to Metana

COD is the amount of oxygen required to oxidize organic substances present in water samples or the amount of oxygen required to oxidize organic substances into CO_2 and H_2O (Carawan *et al.*, 1979). In this reaction, any substance, in the ammount of 85%, canvirtually be oxidized to CO_2 and H_2O under acidic conditions. The analysis of COD effluent treatment in anaerobic bioreactor could be seen in Figure 5.

Figure 5 showed that treatment with a loading rate of 0.5 L / day and 1.0 L / day of COD were the same, but the increase in the rate of loading increase the value of COD. Khaerunnisa *et al.* (2013), states that the provision of COD overload on the anaerobic bioreactor will cause at least COD. These were due to a growing number of organic materials which reformed into volatile fatty acids and volatile fatty acids exceed methanogenic bacteria lead to the accumulation of volatile acids that can inhibit the removal of COD (Sanchez *et al*., 1994).

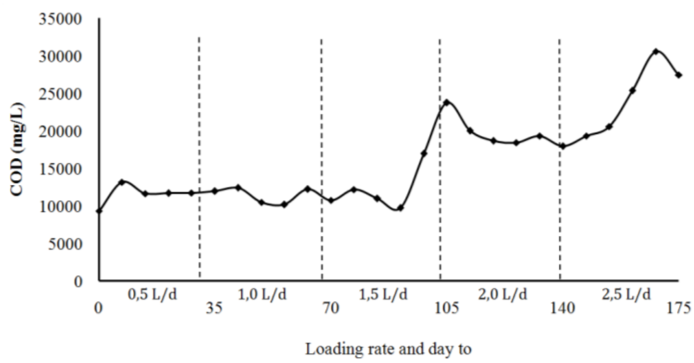

Figure 5. The average COD value of the bioreactor outlet

The degradation of COD in a bioreactor can illustrate the effectiveness of microorganisms in overhauling the organic material into biogas. The higher the value of COD, the more organic matter decomposed into biogas. Figure 6 showed the amount of COD removal at each treatment loading

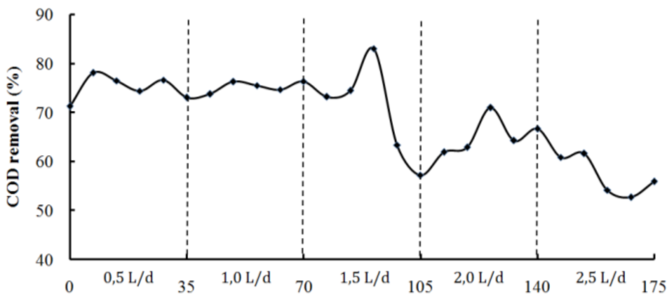

Figure 6. The COD removal at each rate Imposition

Figure 6 showed that the COD value was on the loading rate of 0.5 - 1.0 L / day that had a COD value in the same average level of 75.68 % and 75.28 %. While on the loading rate of 1.5 L / day, 2.0 L / day, and 2.5 L / day, the value of COD is to be down. The impairment is due to limitations of microorganism ability to break down organic material contained in the anaerobic bioreactor.

As the mixture substrate, the manure addition in POME was able to improve the production of biogas. It is because of the organic material contained in the substrate (Kaparaju *et al*., 2009). The production of biogas to the loading rate of organic material could be seen in Figure 7.

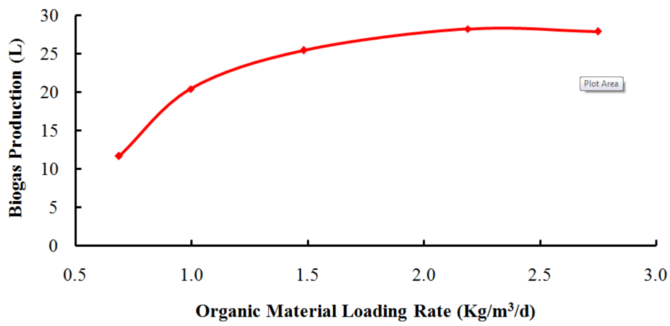

Figure 7. Effect of Organic Material Loading rate to the Biogas Production

Figure 7 shows that the loading rate of 0.6871 kg / m^3 / day to 2.1884 Kg / m^3 / day can increased the volume biogas from an average of 11.65 L to 28.17 L, but in addition the rate of loading up 2,7498 Kg / m^3 / day has decreased to 27.86 L. The decreased production of biogas was caused by methane bacteria in part be carried out in anaerobic bioreactor with the flow of effluent (washed out), so that the amount of methane bacteria in bioreactors decreased (Kaparaju et al., 2009). It led to the organic material in the waste water did not quickly decompose because the number of methanogenic bacteria was not enough, so the COD was still relatively high.

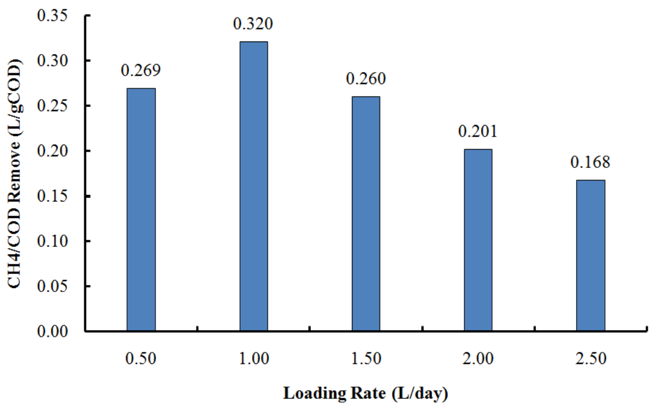

Figure 8. The effect of imposition against the Value Conversion rate of COD removal into Methane

COD can be used as one indicator of the success of the process of anaerobic treatment. The greater the reduction in COD value indicates the better the ability of bacteria to decompose organic matter contained in wastewater (Hasanuddin *et al.*, 2007). COD content of the substrate is the potential amount of organic material to be converted into biogas in an anaerobic fermentation process. The amount of COD conversion value as organic matter into methane gas could be seen in Figure 8.

In Figure 8, it could be seen that the higest value of COD conversion into methane was on the loading rate of 1.0 L / day or hydraulic residence time of 50 days in the amount of 0.320 L CH_4 / g COD. While the lowest value of COD conversion was on the loading rate of 2.5 L / day amounting to 0.168 L CH_4 / g COD. The conversion value of COD into methane gas at STP conditions (Standard, Temperature and Pressure) was 0.35 L CH_4/g COD. Based on the research results, the best conversion value was 0.320 L CH_4 / g COD or 0.233 g CH_4 / g COD. The conversion result increased based on study conducted by Sarono et al. (2014) using substrates 1 L POME that is 0.28 L CH_4 / g COD at a temperature of 55 ° C and a hydraulic residence time of 42 days.

(2) Biogas Production

The formation of biogas, conducted by anaerobic fermentation, is a process conducted by a consortium of microorganisms involving a number of different bacteria. This decomposition process generally consists of four types of reactions, namely hydrolysis, asidogenesis, acetogenesis and methanogenesis (Norfadilah *et al*., 2016). The results of measurements on each biogas anaerobic bioreactor could be seen in Figure 9.

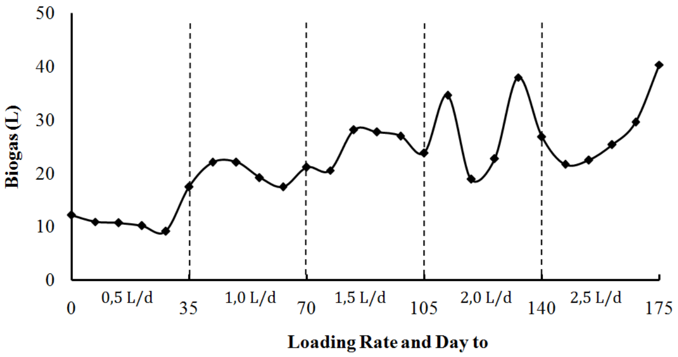

Figure 9. The effect of rate of imposition of the Biogas Production

Figure 9 showed that the increasing of biogas production was based on the addition of volume loading rate of 0.5 L/day to 2.5 L/day. Although the hydraulic residence time is getting shorter, but this treatment provided enhanced biogas production. It could occur due to the addition of methanogenic bacteria in cow dung. In addition, the manure contains a lot of ammonia that is capable of maintaining the pH remains neutral so that all microorganisms can effectivelly work

(3) The content of Methane and Carbon Dioxide

Methane is the simplest hydrocarbon gaseous chemical formula CH_4. Methane is a tetrahedral molecule with four C-H bond equivalent. Biogas composition measurement results on several treatment loading rate could be seen in Figure 10.

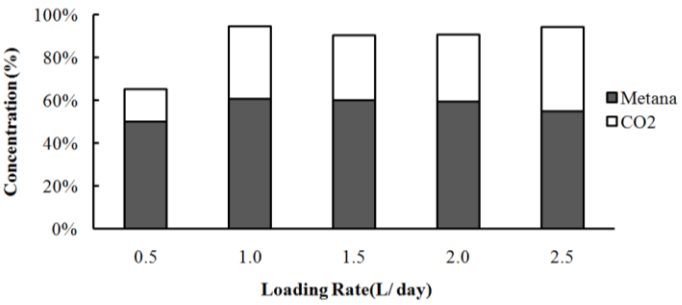

Figure 10. The Composition of Biogas in each treatment of loading

Based on the figure 10, it could be seen that the higest methane produced was 60.49%, on the loading rate of 1.0 L/day. The lowest concentration was 49.85 % on the loading rate of 0.5 L/day. In general perspective, the difference concentration of methane did not have significant difference for any increase in the rate of loading COD with a deviation of 8.63

CONCLUSION

Biogas production using CSTR bioreactors with mixture substrate of POME and manure reached optimal conditions at the loading rate of 1.0 L / day or OLR 0.9956 Kg / m^3 / day. At the loading rate, the higest value of COD conversion into methane was 0.320 LCH_4 / g COD removal or 0.362 LCH_4 / g COD removal and the highest methane concentration was 60.49%.

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