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Potential of Palm Oil Empty Fruit Bunch as Biogas Substrate

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Abstract: Natural gas is a source of energy that comes from the earth which is depleting every day, an alternative source of energy is needed and one of the sources comes from biogas. There is an abundance of empty fruit bunch (EFB) that comes from palm oil plantation that can become a substrate for biogas production. A methodology of fermentation based on Verein Deutscher Ingenieure was used to utilize EFB as a substrate to produce biogas using biogas sludge and wastewater sludge as inoculum in wet fermentation process under mesophilic condition. Another optimization was done by adding a different water ratio to the inoculum mixture. In 20 days, an average of 6gr from 150gr of total EFB used in each sample was consumed by the microbes. The best result from 20 days of experiment with both biogas sludge and wastewater sludge as inoculum were the one added with 150gr of water that produced 2910ml and 2185ml of gas respectively. The highest CH_4 produced achieved from biogas sludge and wastewater sludge with an addition of 150gr of water to the inoculum were 27% and 22% CH_4 respectively. This shows that biogas sludge is better in term of volume of gas that is produced and CH_4 percentage.

Keywords: Biogas, Palm Oil, Empty Fruit Bunch, Fermentation, Mesophilic, Inoculum.

1. INTRODUCTION

Palm oil (Elaeis Guineensis) is a plant that produces oil and is expended everywhere throughout the globe. One of the most important producers of palm oil in the global is Indonesia, generating 37.5 million tons of palm oil. This plant was first discovered in 1911 and has been developed since 1970. Palm oil processes produce several kinds of waste. The processes from fresh fruit bunch (FFB) into crude palm oil (CPO) produces by-products like empty fruit bunch (EFB), mesocarp fiber (MF), palm kernel shell (PKS), palm kernel meal (PKM), and palm oil mills effluent (POME). The waste generated from this process is abundant and being neglected by the producer. Waste from palm oil processes has the potential to gain an economic value because it can be used as a source for chemical compounds, biomaterials, alternative fuel, and fertilizer.

In 2015 Indonesia used 130.35 million tons of palm oil FFB. The life cycle of palm oil plant is around 25 years of effective duration and there are 11.3 million hectares of land use in Indonesia, from this statistics it is expected that there are approximately 30.61 million tons of EFB produced (Hambali and Rivai, 2017). This high energy containing waste can be used as a fuel source for energy production. Energy source from fossil are depleting in a rapid rate and there is still a lot of remote areas that has no electricity running in their area. Biogas has the potential to be the energy source for electricity, cooking, and lighting in Indonesia especially remote area.

Based on this data, the objective of this thesis is to use and optimize the waste products from CPO production, countrywide plantations and industries, specifically EFB as a fuel source for biogas production because large amounts of EFB are produced every year from this process. The biogas can later be used as fuel for electricity generation, cooking gas, or lighting. The objective of this experiment was to know which type of inoculum (biogas sludge or wastewater sludge) gave the best result in term of total volume and gas quality (CH4, CO2, H2S, and microbes population).

2. RESEARCH METHOD

The samples of empty fruit bunch and sludge were taken from a biogas plant in Belitung. The experiment was conducted from February 2018 until June 2018. Experiment, data taking, and data analysis were done in the Laboratory at Swiss German University, Alam Sutera, Tangerang, Indonesia. The experiment was done in the mesophilic state (temperature kept at $\pm 35^{\circ}$C) and 6 treatments are conducted as in Table 1.

Table 1. Experiment design of biogas production

Sample	Type of Inoculum	EFB (gr)	Inoculum (gr)	Water (gr)	Ratio
A	Biogas Sludge	150	300	300	1:1
B	Biogas Sludge	150	300	150	2:1
C	Waste Water Treatment Sludge	150	300	300	1:1
D	Waste Water Treatment Sludge	150	300	150	2:1
E	Biogas Sludge	150	300	0	1:0
F	Waste Water Treatment Sludge	150	300	0	1:0

Microbes in the initial sludge were analysed in term of quantity to determined the activeness of the sludge itself. The analysis of microbes population was done by the worker in Pusat Penelitian dan Pengembangan Teknologi Minyak dan Gas Bumi (PPPTMGB) Lemigas, Jakarta with microbes population procedure based on APHA 9215 method. Fermentation test apparatus was built as specified in DIN 38414 Part 8 or as specified in DIN EN ISO 11734 (Verein Deutscher Ingenieure, 2006). The equipment and materials that are used to run in this experiment must be absent from atmospheric oxygen or gastight. The system that is shown in Figure 1, will collect gas by storing the produced biogas in the eudiometer tube.

Figure 1. Fermentation Setup Apparatus

The pretreatment done to the EFB is size reduction pretreatment that is chopped to smaller pieces. The quantitative determination of CH_4, CO_2, and H_2S were done by using Portable Biogas Analyzer SAZQ and for the volume of gas produced was done by looking at the drop of the sealing liquid (Sperrflüssigkeit) in the eudiometer. The temperature of the hot water bath was maintained by using a controllable heater and digital thermometer. Experiment procedure flow can be seen in Figure 2.

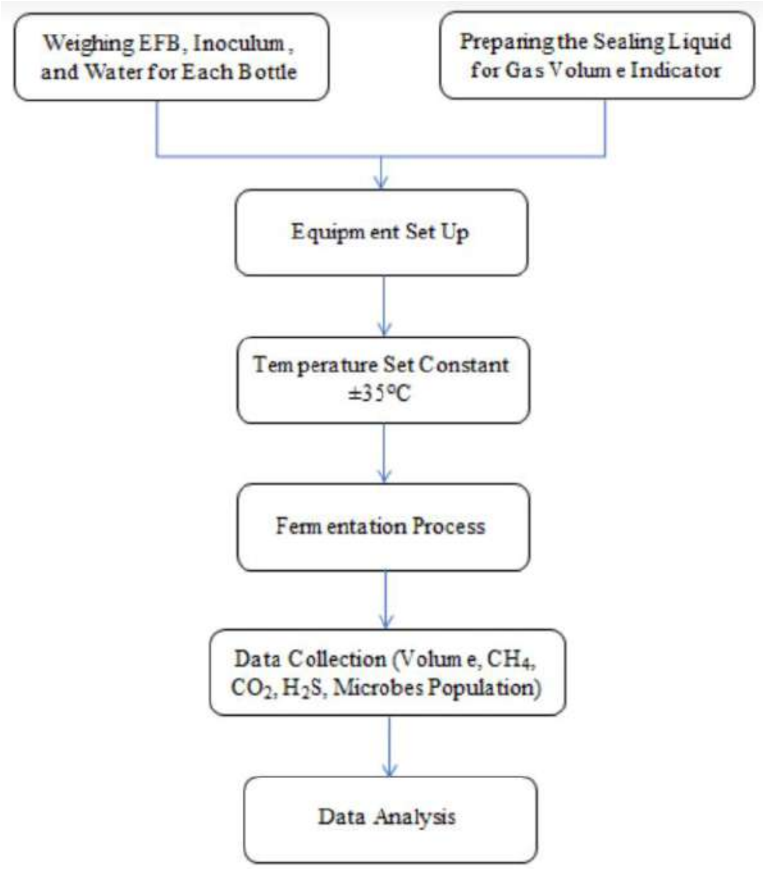

Figure 2. Experiment Flowchart

3. RESULTS AND DISCUSSION

Table 2. Before and After Experiment EFB Weight

	A	B	C	D	E	F
Before	150 gr	150 gr	150 gr	150 gr	150 gr	150 gr
After	143 gr	140 gr	145 gr	143 gr	146 gr	146 gr
Consumed	7 gr	10 gr	5 gr	7 gr	4 gr	4 gr

After the experiment is finished the EFB is then dried and then weight again to know how much has been converted during the process. The average amount of substrate that is consumed by the microbes is 6 gr from 150 gr EFB used can be seen in Table 2. There are other organic substances in EFB but since cellulose is the dominant part, it will the one that is going to be calculated. Theoretically, 1 gr of cellulose if all were converted into CH4 there should be 414 ml of CH4 per gr of cellulose (Hafner and Rennuit, 2018). The composition of EFB shows that 45% of the fruit is cellulose (Darmosarkoro and Winarna, 2001). Theoretically, the max CH4 that can be produced from 6 gr of EFB can be seen in the calculation below:

$$6\ gr\ x \frac{45}{100} = 2.7\ gr\ of\ Cellulose \quad (1)$$

$$1gr\ of\ Cellulose = 414\ ml\ of\ CH_4 \quad (2)$$

$$2.7\ x\ 414\ ml = 1117.8\ ml\ of\ CH_4 \quad (3)$$

Previous studies from (Agus Purnomo et al, 2018) shows that semi wet fermentation gives the best result and the same one occur here. The result from the combination of 150 gr EFB, 300 gr inoculum, and 150 gr water gave the best result among all the other combination for both inoculums that is used. The data of CH_4 produce and the theoretical value it should have can be seen in Figure 3 below:

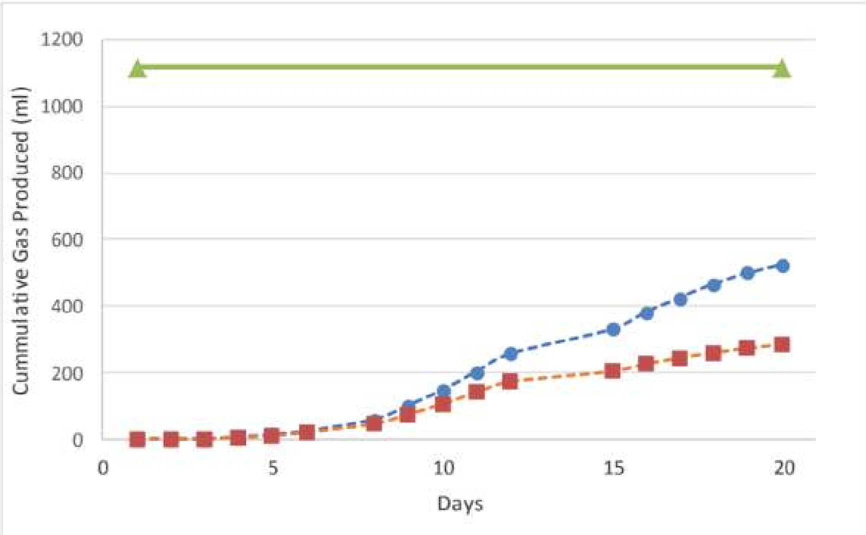

Figure 3. CH_4 produced from 150 gr EFB, 300 gr inoculum, and 150 gr Water for Biogas and Waste Water Sludge; (○) with Biogas Sludge; (□) with Waste Water Sludge; (∆) Theoretical CH_4 Value.

Figure 3 result shows quite a big gap between theory and the actual result. It is happen because not all gases that are produced from the microbial activity turn into CH_4 but turn into CO_2 from what is shown in the biogas analyzer. Since the feedstock is relatively hard to degrade, only a small amount of soluble organics is available for conversion into CH_4 and this could explain for more CO2 content. Gas is still being produced when the experiment was stopped. This shows that the production of gas is more than 20 days to reach the theoretical data.

The substrate used which is EFB and both of the inoculum used was not pretreated during this experiment. A pretreated EFB can be done in mechanical, thermal, biological, or chemical treatment that can lead to an increase in biogas production because microbes that degraded cellulose, hemicellulose, and starch can works easier with a simpler substrate that will speed up the degradation of substrates and increase in biogas yield. (Montgomery, L and Bochmann, G. 2014). Pretreatment of inoculum can also increase the yield of biogas production by adding the substrate to the inoculum first before inoculum is then used in the biogas production process. The pH is then set between 4 and 6 and temperature to be either mesophilic or thermophilic state (30-50oC), this process will inhibit the methane production process and the acid in the sludge will be accumulated so that when the sludge is going to be used as inoculum the methanogenesis process can start immediately because an optimal and effective environment for the microbes are available. (Deublein and Steinhauser, 2010; Thauer, 1998).

The system run here have no mixing so contact of the substrate with microbes are not effective. Mixing in digester homogenized the spread of active microbes with the substrate or feed in it. This can cause an increase in biogas yield (Lindmark J, Thorin E, Fdhila R, Dahlquist E. 2014). There is a contact between sample and oxygen during pH measurement. It happens because the bottle filled with sample has to be removed from the eudiometer to measure pH. This can also affect inhibition during the anaerobic fermentation process. (Botheju D, Lie B, Bakke R. 2009).

Table 3. Microbes Population of Waste Water and Biogas Sludge

Inoculum	Test Type	Result	Unit	Method
Waste Water	Microbes Population	3.6×10^3	cfu/mL	APHA 9215
Biogas Sludge	Microbes Population	8.9×10^5	cfu/mL	APHA 9215

Biogas sludge was used because hypothetically there is already some bacteria that can do anaerobic digestion processes since it is sludge generated from a biogas production while wastewater was use to compare the result since this water at first supposed to not have any bacteria related tobiogas production.

From the data in Table 3. biogas sludge have microbes population of 8.9×10^5 and the one in wastewater treatment sludge have microbes population 3.6×10^3. As expected from the data of gas produce and gas quality graph result shown that fermentation using biogas sludge as inoculum will have the better result than the one using wastewater treatment sludge as inoculum. It happens because the sludge from biogas process is sludge that is actively used in biogas production at the palm oil factory therefore, there will be more activity of microbes than the one from wastewater treatment sludge and that is why using biogas sludge will boost the startup process of biogas production. (Verein Deutscher Ingenieure, 2006).

Because there is no data for the composition of the microbes, estimation can be made from the behavior of the experiment result. Biogas production consists of 3 steps; hydrolysis, acetogenesis, and methanogenesis. All of this process required different microbes to work. (Conrad, 1999 and Parawira et al., 2008). Acid production in acetogenesis proses will cause a drop in pH (de Bok et al., 2005 and Schink, 1997). The pH result shows that there is a drop during experiment so acetogenic bacteria exists in both of this sludge. While producing acid, microbes will also produce a byproduct of H_2S. The amount of H_2S from the experiment using biogas sludge is higher than the one using wastewater sludge. This proof that acetogenic microbes are superior in the biogas sludge rather than in wastewater sludge.

Methanogenesis process produced CH_4 and CO_2. The result in Figure 3 shows that the rate of CH_4 forming in Biogas sludge is higher than the one using wastewater sludge. It means that methanogenic microbes exist more in the biogas sludge rather in wastewater sludge. The rate of methane production can be increased by pretreating the sludge before use (Getachew and Jenicek, 2016). Both inoculums have all the microbes needed to run the process of biogas production. But the microbes composition and population is far more superior in Biogas Sludge.

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