Production Biomethane from Palm Oil Mill Effluent (POME) with Truncated Pyramid Digester in Fed Batch System

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Abstract. Palm oil mill effluent (POME) production in Indonesia is estimated around 63 million ton/year [1]. Therefore it is a potential source of contamination when it directly discharged into the river. Even though, POME will be as raw resource biogas production. The aims of this research were to know the effect of fermentation time toward biogas production in truncated pyramid digester. The study was done in three combinations of feedstock with POME concentrations of 90, 80, and 70% and activated sludge concentrations of 10, 20, and 30%. A mixture of POME and activated sludge at 6 L/minutes for 30 days were fed into the digester. The result showed the fermentation time gave significant effect toward biogas production in the truncated pyramid digester. All combinations showed the upward trend in the volume of biogas during fermentation. The highest quantity of biomethane in biogas was 25% mol that the active microbes were added to POME in the ratio 1: 9 in a fed-batch system.

Keywords: biomethane, fed-batch, palm oil mill effluent (POME), truncated pyramid digester.

1. Introduction
Palm oil mill effluent (POME) is wastewater generated by palm oil mill mainly from condensate stew, hydrocyclones water and sludge separator. Every ton of fresh fruit bunches (FFB) processed formed about 0.6 to 1 m3 POME. POME is rich in organic carbon with chemical oxygen demand (COD) of 40 g/L and total nitrogen of approximately 0.5 g/L.

The fermentation process takes place in an anaerobic digester with the aid of bacteria. This process can be done in batch or continuous. In a continuous process, the substrate is inserted every day at certain flow rate corresponding to the retention period. The substrate is derived from a material that is rich in organic matter and mixed by activated sludge derived from manure as an activator. Nutrient content in manure varies depending on the state level of production, the type and amount of feed, as well as individual animals themselves [2]. Nutrient content in manure, such as nitrogen (0.29%), P2O5 (0.17%), and K2O (0.35%) [3].
Biogas digestion consists of four stages of reaction that requires optimum conditions at each stage, if there are no optimum conditions, often the formation of biogas becomes obstructed and sludge still has the potential to produce biogas. In an effort to optimize the production of biogas, the fermentation process is done in two steps with two digesters interconnected. One of them can be done by assembling the digester interconnected in two stages.

Based on this, the authors conducted a study of wastewater treatment process of POME into biogas used by microorganisms as the activator. This research is expected to represent the real situation as possible so that it can be used to produce an environmentally friendly alternative energy. These technologies include the tank (biogas reactor) truncated pyramid-shaped. Truncated pyramid shape was chosen due to avoid channeling occurs in the bottom of the pool for their deposition. At the top of the reactor by the cover is that the methane gas trapped above the surface and can be converted to produce energy.

This technology generally avoids greenhouse gases, especially methane escape into the atmosphere. The subsequent processing stages can also be done with a truncated pyramid-shaped digester to treat of POME more effectively and efficiently. Methane gas as one of the products from oil POME can be accommodated and utilized to energy as compared to released into the atmosphere and added to greenhouse gas emissions. The other products, Sludge, can be used as a liquid fertilizer which is applied to palm oil plantations. Industrial liquid waste processing palm oil at the stage of sedimentation by using this design tool is one way that is more effective and efficient in terms of place, time, and cost of processing.

The purposes of this study include:

- Determine the influence of starter volume percentages given in POME in the digester to the quantity of biogas produced.
- Determine the influence of fermentation time on POME to the quantity of biogas by using a truncated pyramid-shaped digester on fed-batch system

2. Methods

2.1 Fermentation anaerobic for activator microorganism
The active microbes were added to POME in the ratio 1:4 L in a batch bioreactor with a volume of 8 L. Temperature and pH on anaerobic fermentation were not regulated, whereas the sampling time, each day with as much volume of 1 L and 1 L of water was replaced with POME.

2.2 Fermentation anaerobic for biogas production
Main raw material substrates of POME are pumped into the first tank to the brim. This tank serves as shelter bait. Feed that has been entered into the first tank will undergo deposition (sedimentation). The substrate will be divided into two layers. The bottom layer will be a rich substrate in the form of the slurry and the top layer of substrate that has been separated from the slurry.

The top of layer flowed into the second tank after deposition for 24 hours. In the second tank of POME mixed with a starter. Digester used with a truncated pyramid-shaped fed-batch type with a capacity of 18 L. The mixture of POME and starter varied by comparison wastewater and starter 10:90, 20:80, and 30:70. POME from the tanks streamed every day and also continuously added a
starter. The fermented liquid in the tank to be also streamed every day two to three tanks to prevent in the second tank so on until the gas obtained in the variant designated day (Figure 1).

![Figure 1](image)

**Figure 1.** The design of the truncated pyramid-shaped measurement in processing of POME on biogas production

Note:

- Tank 1: Bioreactor for sedimentation
- Tank 2: Bioreactor for fermentation
- Tank 3: Bioreactor for collection
- Tank 4: Tank for collection of slurry

### 2.3 Analytical analysis

All the tests for the samples were analyzed according to the guidelines of the American Public Health Association [4] for the examination of POME and POME after fermentation. Biogas yield was measured with a wet gas meter (W-NK-O-SA, Shinagawa). Gas samples were obtained through an inverted funnel placed above baffles near the top of the reactor. Biogas composition was determined using a gas chromatograph (GC-8A, Shimadzu, Kyoto).

### 3. Results and Discussion

#### 3.1 Raw materials analysis

POME is analyzed by nitrogen content, pH, COD, and BOD to get treatment in the sewage treatment pyramid-shaped anaerobic digester. POME as substrate was fermented to produce biogas. The results of the analysis of the substrate can be seen in Table 1
Table 1. Analysis Data from POME

| Parameter         | Result from this research | Kep Men LH 51       |
|-------------------|---------------------------|---------------------|
| pH                | 4                         | 6.0-9.0             |
| BOD (mg/L)        | 1755                      | 250                 |
| COD (mg/L)        | 26352                     | 350                 |
| NH₃ Total (mg/L)  | 199.36                    | 50                  |

The results of the analysis of the chemical characteristics of POME from PT. Mitra Ogan (Table 1) shows that the waste has a pH of 4, BOD 1,755 mg/L, COD 26,352 mg/L, nitrogen 199.36 mg/L. The overall parameter is above the threshold value the quality standards set by Kep Men LH 51, 1995 (Table 1), so that POME which has a high organic matter content has the potential to be used as a substrate in the process of anaerobic fermentation. Biological treatment and in the process uses microorganisms to degrade organic pollutants [5] worthy recommended as the appropriate processing method. According to Davis and Cornell (1991) [6], the content of BOD in excess of 1,000 mg/L makes the anaerobic process to be applied as a pretreatment.

COD from POME is 26,352 mg/L. COD value is much lower when compared with studies Lang, (2007) [7] in the amount of 50,000 mg/L and is still smaller than research Hasanah, (2011) [8] is 47105.26 mg/L. COD is a measure of the quantity of organic material in the wastewater that showed high content in the form of lipids, carbohydrates, and proteins. According to Zhang et al (2008) [9], the processing potential of anaerobic fermentation is done for handling POME due to high organic material characteristics. Additionally, effluent BOD value of palm oil mill is 1755 mg/L is still the very high content of organic material so that the value of TDS and TSS is high anyway.

Based on the analysis, the total nitrogen content of POME is in the range approaching the total of nitrogen. According to Simamora et al. (2006) [10], C/N ratio that is optimum for the microorganisms is 20-25. Therefore, the liquid waste used as a substrate in the process of anaerobic fermentation. Sources C and N necessary microbes involved in the anaerobic process as a source of nutrients for growth and development of the microbes. If the N content in the substrate slightly, then the bacteria cannot produce the enzymes needed to synthesize the compound (substrate) containing carbon. Meanwhile, if the substrate is too much to contain N, bacterial growth is inhibited due to the ammonia contained in large quantities [11].

3.2 Analysis of Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD)
COD is used as a measure of the quantity of organic material in the wastewater industry-and the potential to produce biogas [12]. In the reform process of anaerobic, which is biodegradable COD present in the organic material and the resulting end product called methane and past the newly formed bacteria. Measurement of COD value in the wastewater end of the palm oil industry after the fermentation process in the digester is shown in Figure 2.
Based on the analysis, a combination of POME and starter has a significant influence on the COD value in the end. It can be seen that the value of COD in waste water mixture of palm oil and cow dung after undergoing a process of anaerobic fermentation decreased from 26,352 mg/liter before treatment to 135 mg/liter for the first sample and 110 mg/liter and 90 mg/liter for each of the second and third samples. This indicates that the POME waste containing high pollutant loads and can be dropped using the process of anaerobic fermentation processing. The content of organic substances in the effluent POME has been degraded by microbes active from cow dung so that the organic material has been changed and its COD value decreases. According Nugrahini et al. (2008) [13], COD is an important variable that indicates success or failure of the process of degradation. Overall COD measurement detects organic compounds, both organic as well as simple organic compound [14]. According Kresnawaty (2008) [15] due to impairment COD has become the hydrolysis process. At this stage of organic materials utilized by microorganisms as nutrients and convert it into a form simpler compounds.

As for the measurement BOD value in POME after the fermentation process in the digester is shown in Figure 3.
The Figure 3, it can be observed that the reduction in BOD loadings occur in POME occurs due to the influence of the reduction in COD where the value of the initial BOD content before getting treatment in the digester pyramid. This reason is POME contains high pollutant loads and can be dropped using the process of anaerobic fermentation processing.

POME is dumped directly into the environment will cause environmental pollution, therefore, to reduce COD and BOD concentration required treatment in the form of waste treatment in the pyramid-shaped digester with a sedimentation process. The decrease of COD and BOD happens after treatment because some organic substances in the waste has been degraded into sludge and others have been degraded into other products such as methane [16]. Although at the sewage treatment of COD and BOD has decreased, but still need to do the processing for the reduction of COD as low as possible by regulations made by the government of Kep. MEN-LH No. Kep-51 / MENLH / 10/1995 dated October 23, 1995, where the quality of raw palm oil industry waste ready to be released into the receiving water body or the environment should have a maximum COD value of 500 mg / liter and maximum BOD of 250 mg/L.

POME has a high organic matter content and containing macro nutrients such as nitrogen (N), phosphorus (P) and potassium (K). Analysis of total nitrogen content before and after getting treatment by sedimentation processes in the pyramid-shaped digester is shown in Fig. 4.

![Figure 4. Total Nitrogen Levels Before and After Anaerobic Fermentation Process](image)

After analysis of sludge produced, sludge wastewater treatment results of POME by means of sedimentation has a total nitrogen content of the previous 199.36 mg/L to Rp 38.08 mg/L for the first sample while samples in second and third respectively are 36.84 mg/L liter and 28 mg/L. This figure is already approaching the levels nitrogen of POME, so it could potentially be used as a liquid fertilizer
for palm oil plants, which can automatically replace the use of chemical fertilizers price is too expensive. In addition to reducing waste disposal to the environment and can save processing costs.

### 3.3 Effect of time and ratio on methane production

Gas production from POME and starter using truncated pyramid digester system result fed laboratory-scale batch volume of 18 litres shows the whole combination showed the trend of increasing volume of biogas fermentation. The highest quantity of CH$_4$ is 24.95865% mole in ratio 10:90, while the lowest quantity of CH$_4$ is 9.4782% in ratio 30:70. Each variation of the mixture composition shows fermentation time significantly affected the production of biogas. Wherein an increase in CH$_4$ composition during the 30 days of fermentation, as shown in Figure 5.

![Figure 5. Effect on Time and Ratio on Methane Production](image)

The optimum percentage of methane concentration in optimum condition 30 days with a volume ratio of starter and liquid waste, 10:90, is 9.4782%. The percentage of gas in the ratio of 10:90 raw material are the compared with a ratio of 20:80 and 30:70 raw materials. However, the percentage of CH$_4$ always rises until the 30th day. The percentage of gas for 30 days of fermentation will experience enhancement with increasing fermentation time. According to research [17], the longer the fermentation time the increased activity of microorganisms to use a substrate so that it will affect the resulting product. On the 6th day of the first quantity produced was 2.9824%. The lower the percentage of CH$_4$ in this comparison due to the many factors that lead to microbial activity stops, such as pH and temperature factors so that microbes do not work optimally in overhauling the substrate. Such data has been shown in Table 1, the initial pH of POME that is 4. After the addition of the mixture to starter, the pH will increase. The reason is the pH value on anaerobic processes will decline with volatile acids produced and will increase with volatile acids consumed by methane forming bacteria [18]. If the pH drops below 6.5, the organic acid began to take shape with the help of hydrolytic bacteria and fermentation stage begin to stop. Methanogenic bacteria are very sensitive to changes in environmental pH. The pH value of 10 best in producing biogas ranged from 7.0. If the pH value below 6.5, the activity of methanogenic bacteria will decrease and pH below 5.0, the fermentation activity will stop [11].
The combination 20:80 of gas production in the digester produces truncated pyramid CH4 percentage is 9.8200%. Gas production on a combination was higher than 10:90 combination. It was explained earlier that the factors that influence differences in gas production in each treatment are the total N content of the substrate, the pH value and the content of nutrients and organic matter content in each mixture. The graph in Figure 5 above shows that in addition there is also the CH4 content of O2 and N2. The content of O2 and N2 looks quite higher than the content of CH4. This affects the fermentation process in the formation of biogas because microbes contained in the substrate cannot work properly if a lot of air contained within the digester. The presence of O2 and N2 content of that magnitude in the digester can occur due to the less closed digester, causing air can enter easily into the digester. The content of O2 and N2 causes a state in no aerobic digester while the methanogenic bacteria are living in anaerobic or minimal O2.

In Figure 5, note that the content of CH4 volume ratio of 30:70 starter and liquid waste is the highest, amounting to 24.95865%. This is the most appropriate composition of the three variations are done. This occurs because the starter, written more than 30% of the remaining mixture is POME with rich organic matter content so that the bacteria were able to remodel perfectly. The organic material will change the protein, cellulose, and fats into amino acids, glucose, and fatty acids. Level of methane in the biogas is affected by the ability of microorganisms to decompose organic substrate and the carbon and nitrogen in the digester.

The graph above shows the relationship quality of biogas against time to the comparison of the volume of each starter and POME. Quantities indicated a significant increase in the ratio of 30% and 70% starter liquid waste. This is because the ability of the bacterial hydrolysis of each comparison is different. Where the organic material from the starter ratio of 30% and 70% of POME is greater than the other resulting in the formation of methane by bacteria more leverage. Besides the comparison between batch and fed-batch systems are presented in Table 2.

**Tabel 2. Comparison of percentage methane in batch and fed batch system**

| System     | Stater:POME | Ferm. time (days) | Conc Methane (%mol) | Ref.             |
|------------|-------------|-------------------|---------------------|------------------|
| Batch      | 30:70       | 4                 | 1.7972              | Saputri (2015)   |
| Fed Batch  | 30:70       | 30                | 24.9586             | This research (2016) |

4. Conclusions
Based on the results of research that has been done is the treatment of POME into biogas fed-batch system, it can be concluded of the three variations of combinations of substrates that starter and POME are 10:90, 20:80, 30:70 shows that the more volume starter is added to the liquid waste then the percentage of biogas produced will be higher. It can be observed in the percentage of methane generated is directly proportional to the volume of starter added.

Time of fermentation in each variation of the substrate, namely a combination of POME and starter 10:90, 20:80, 30:70 by fed-batch system provides real influence on the production of gas, with the
upward trend in gas production during the 30 days of fermentation. Fermentation time is long lead time live feed in digesters longer so that the bacteria can remodel more organic material into biogas.

In further research is necessary to add other nutrients to the substrate so that the result can be a maximum of biogas. In addition, variations in the other livestock manure activators could be in with a longer retention time again.

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