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Effect of Stirring Co-digestion of Palm Oil and Fruith for Biogas Production to Increase Economy Benefit

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Abstract

Effect of stirring on palm oil mill (POME) and empty fruith bunch (EFB) substrate mixture in increasing the biogas production is done at batch reactor with 8 liters of working 6 liters with thermophilic temperature. Co-digestion POME and EFB were performed by varying the stirring rate (50, 100, 150, 200 and 300 rpm). The best stirring rate was obtained at 100 rpm stirring which reached 84.82 L/mg.VS and biogas production reached 88.53%, and VS reduction of 20.30%.

Keywords
stirring; POME; EFB; biogas; thermofilic; co-digestion

I. Introduction

Population growth in the world has boosted the need for fossil fuel energy. Badan Pusat Statistik (2016), notes that the population of Indonesia is ranked 4th largest in the world after China, India, United States. The total population of Indonesia from the results of the 2016 census reached 258,316,051 inhabitants. Along with the increasing number of population hence resulted in increasing requirement of fuel oil (BBM).

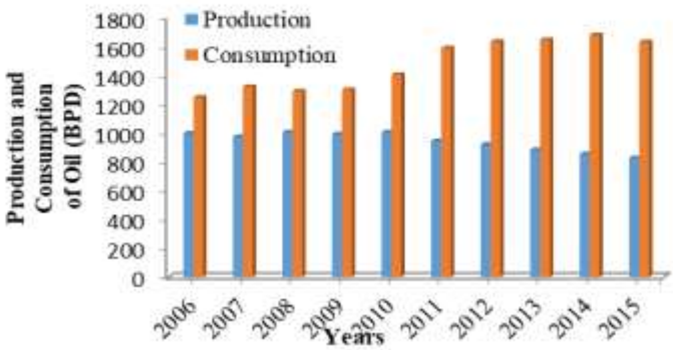

Figure 1. *Production and Consumption of Oil at Indonesia*
(Source: Badan Pusat Statistik, 2016)

Palm oil liquid waste (LCPKS) reaches ±82.5 million tons in ±33 million tons of palm oil production by 2015 (Wright and Rahmanulloh, 2015). Najafpour et al. (2005), stated that in addition to wastewater, large quantities of solid waste such as empty fruit bunches (EFB) (23%), mesocarp (12%) and shell (5%) for each ton of fresh fruit bunches (TBS) are processed in factory, because both types of waste is more dominant than other waste, hence from this waste is used for biogas production.

According to Ali et al. (2013), biogas is a type of biofuel, whose components consist mainly of methane and carbon dioxide. EFB is a lignocellulosic material consisting of carbohydrate sugars, lignin, with inorganic minerals (Hamzah et al., 2016). Nurliyana et al. (2015), states that EFB is one of the most widely produced palm oil production after palm oil mill effluent (POME) whereas the POME is one of the byproducts of palm oil mills derived from sterilization process condensate water (36%), water clarification process (60%), and hydrocyclone water (4%) Bala et al. (2014), Embrandiri et al. (2012).

POME could be easily converted to biogas in relatively short time (HRT 6 days) then used in many applications, while solid waste are not utilized for biogas production, due to its composition are difficult to degrade by microorganisms (Octiva et al., 2018).

In the research conducted by Trisakti et al. (2014), the processing of LCPKS with CSTR reactor with 50, 100, 150 and 200 rpm variations of stirring resulted in the highest biogas production at 100 rpm stirring at 40 kg/m3 VS. In the research of Shen et al. (2013), the processing of rice straw with CSTR reactor obtained the highest biogas production at 80 rpm stirring that is obtained 431 mL (g VS)-1. In addition to the research conducted by Keanoi et al. (2014), biogas production and the highest methane concentration was obtained at 98.56 L/day and provided a 7.56 increase in the digester. This suggests that agitation can be used effectively as an operating strategy to optimize biogas production. Therefore, it is necessary to vary the stirring rate at POME and EFB to see the best stirring rate.

This research was conducted to see the effect of stirring on POME and EFB substrate with batch reactor with 6 liter working volume.

II. Research Methods

2.1 Collection and Preparation of Material Raw

Data collection techniques are methods used to collect information or facts in the field (Pandiangan, 2018). Data collection techniques are a vital part of a research process. This technique is divided into two, namely qualitative and quantitative. In short, the technique or method of data collection is one of the research methods to collect various data or information contained in the field.

According Pandiangan et al. (2021), the preparatory stage is carried out before starting research activities. This stage consists of studying literature and preparing tools and materials to be used in research activities. The palm oil mill (POME) and empty fruith bunch (EFB) is obtained from the fat pit factory of PKS rambutan, North Sumatra. POME stored at 4℃ in the freezer temperature at Ecology Laboratory, Universitas Sumatera Utara (USU). EFB dried under the sun for one day one night, subsequenly EFB were cut for reducing the particle size ±5 cm.

2.2 Experimental Design

Experimental design is one form of experimental research, because in this design the researcher can control all external variables that affect the course of the experiment. Thus the internal validity (quality of the implementation of the research design) can be high (Tobing et al., 2018). Experimental design is a quantitative research method used to determine the effect of the independent variable (treatment) on the dependent variable (outcome) under controlled conditions (Pandiangan, 2015). The condition is controlled so that there are no other variables (other than the treatment variable) that affect the dependent variable. In order for conditions but different mixing. Digester A was run under continuous mixing of 50 rpm, 100 rpm, 150 rpm, 200 rpm and 300 rpm.

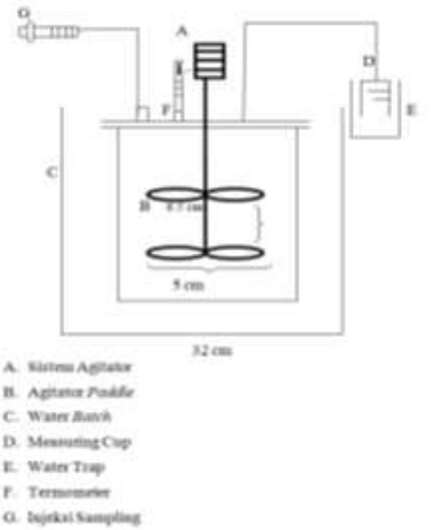

Figure 2. *Bath Reactor Analytical Determination*

Alkalinity was measured by direct titration method Jenkins et al. (1983), the TS, VS, TSS and VSS and gas analyzes were performed daily, whereas the COD analysis was done once every three days, TS, VS, TSS, and VSS and COD analyzes was done by examination of water and wastewater APHA (2005), while CH4 analysis was analyzed by gas analyzed detector.

III. Discussion

The analysis results of POME Table 1 shows that POME has substrate with has high amounts of pH, COD, VS and VSS.

Table 1. Results of POME

Parameter	Test Result	Test Method
pH	3.70-4.70	APHA 4500-H
Chemical Oxygen (Demand (COD)*(mg/L)	48,300	Spectrophotometry
Total Solid (TS) (mg/L)	13,420-37,020	APHA 2540B
Volatile Solid (VS)(mg/L)	10,520-31,220	APHA 2540E
Total Suspended Solid(mg/L)(TSS)	2,080-27,040	APHA 2540D
Volatile Suspended (mg/L)Solid (VSS)	1,920-25,800	APHA 2540E

3.1 Effect Stirring to pH and Alkalinity

pH is one of the most influential biogas production parameters (Susmita and Tenneti, 2015). Alkalinity and pH are related to each other (Kumar, 2012). Alkalinity is a parameter in anaerobic digestion operation which is a measure of the capacity of alkalinity to neutralize acid (Qasim and Chiang, 1994). The effect of agitation on Alkalinity is shown in Figure 3**.**

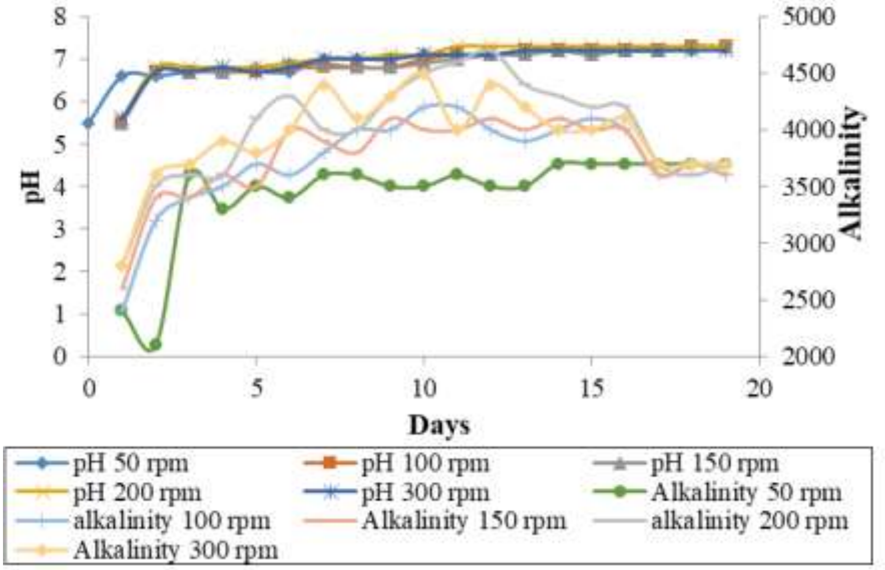

Figure 3. *Effect of Stirring on pH and Alkalinity*

Figure 3 shows that at a change in stirring rate of 50 rpm, 100 rpm, 150 rpm, 200 rpm, and 300 rpm fluctuates against pH and stable Alkalinity. PH indicates system equilibrium and digester stability (Ostrem, 2004). On the first day the pH is still acidic, reaching 5.5 and the second day and then the pH has reached 6.5 to 7.3. However, pH fluctuations are still within reasonable values, ie 5.5-8.5 Ostrem (2004), low pH indicates a process of acidification (Mujdalipah et al., 2014). Acidification is indicated by high acid concentration due to the process of changing the product of hydrolysis to volatile fatty acids such as acetate, propionate and butyrate (Carneiro et al., 2008). The profile of the effect of the stirring rate on the average alkalinity can be seen in Figure 4.

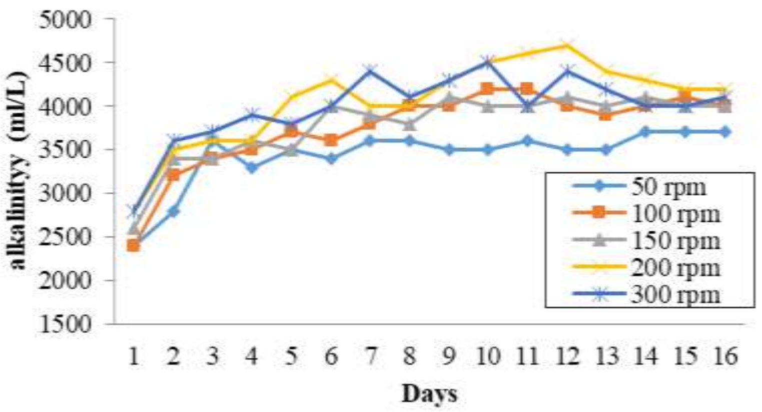

Figure 4. *Effect of Stirring Rate on Alkalinity Average*

Sufficient alkalinity is required for proper pH control (Mun, 2012). Alkalinitas is a parameter that can be used as a measure of the ability of neutralizing excessive production of organic acids in the reactor, so that the pH remains constant (Ghaly et al., 2010). Alkalinity serves as a buffer that prevents rapid pH change. So the alkalinity value is closely related to pH. On the first day of the alkalinity still within the range of 2500 values and the day next day the value of alkalinity is rising and fluctuating. However, the pH fluctuations are still within a reasonable value, ie 5.5-8.5 (Ostrem, 2004).

3.2 Effect of Consistency Ratio against Volatile Solid (VS)

The methanogenic bacterial methanogenesis process converts volatile fatty acid (VFA) into biogas (Krishnan et al., 2016). Volatile solid is also defined as a reliable parameter to indicate the degradation of organic matter over time, and consequently, is an indicator of the potential for methane (Mehta et al., 2002). The effect of consistency on volatile solid (VS) can be shown in Figure 5.

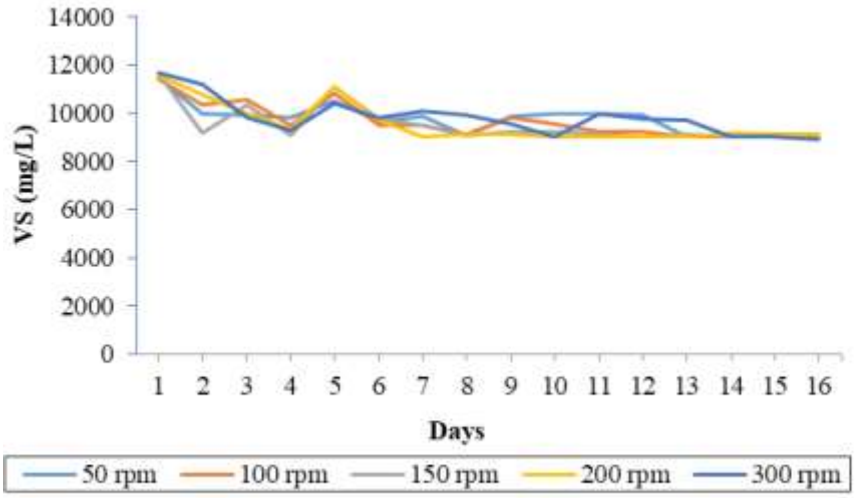

Figure 5. *Effect of Stirring on Volatile Solid (VS)*

Figure 5 shows that at 50, 100, 150, 200, and 300 rpm stirring rates the VS profile shows a fluctuating and ultimately constant value. The best VS profile for each stirring rate can be seen in Figure 6.

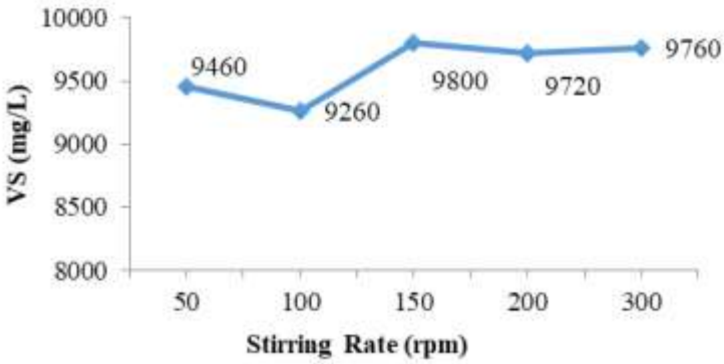

Figure 6. *Effect of Stirring Rate on Best Volatile Solid (VS)*

Figure 6 shows that solid volatile reduction (VS). The best VS reduction value obtained at 100 rpm stirring rate is 9.260 mg/L with reduction VS 20,3098%. In Trisakti et al. (2015), study with 50, 100, 150 and 200 stirring variations, the highest biogas production at 100 rpm was 40 kg/m^{3}VS.

Variation of stirring rate gives a significant impact where along with increasing of agitation rate obtained degradation profile VS decreasing. Therefore in methogenogenesis process of POME with thermophilic condition, optimum agitation rate is obtained at 100 rpm stirring rate with VS reduction value 20.3098%. The higher the reduced VS indicates the more organic matter converted by microbes in the fermentor.

3.3 Effect of Stirring on Biogas Production

The last stage of the anaerobic digestion process is a methanogenesis stage. Table 2 shows the profile of biogas production.

Table 2. Efect Stirring for Biogas Yield and Biogas Production

Stirring Rate (Rpm)	Cumulative of Biogas Production (L/day)	Cumulative Biogas Yield (L/mg.VS)
50	1.63	49.38
100	1.89	65.54
150	1.73	51.40
200	1.68	57.75
300	1.59	42.04

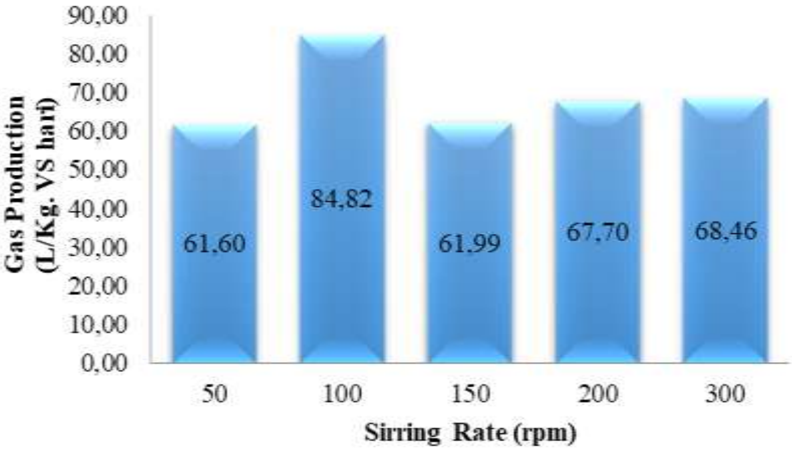

Figure 7. *Effect of Stirring on Biogas Production*

Figure 7 the highest biogas volume is obtained at a 100 rpm ying rate with a value of 66.54 L/mgVS.day. In the study Trisakti et al. (2015), the best biogas producer in 100 rpm stirring at 40 kg/m^{3}VS. Mumtaz et al. (2008), the rapid rate of stirring causes the microbial growth in the fermentor to be significantly impaired.

3.4 Biogas Productivity from Different Stirring

The low concentration of fruith crib substrate produces low methane, because the high content of long chain fatty acids (LCFAs) in EFB can inhibit the degradation process, which contains long chain fatty acids, especially palmitate high also higher oleic that can inhibit bacterial growth and methane formation (Thong et al., 2016). The main components of biogas compounds are methane (CH_4) and carbon dioxide (CO_2). In this study the concentration of biogas is indicated by the concentration methane (CH_4), carbon dioxide (CO_2) and hydrogen sulfide (H_2S). The following is the consistency effect of POME and EFB on the resulting biogas composition. The following is the effect of consistency of POME and EFB on the resulting biogas composition shown in Figure 8.

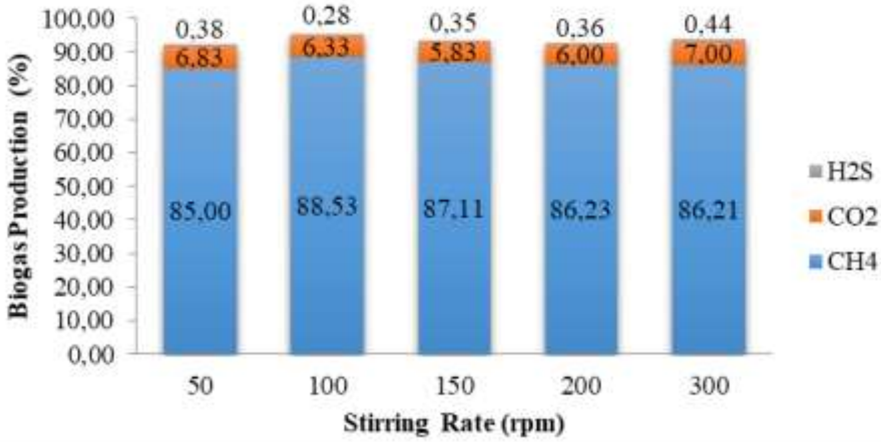

Figure 8. *Effect of Stirring on Biogas Production*

Figure 8 shows that the composition of biogas production. The best stirring rate is obtained at 100 rpm, which is obtained value of methane, carbon dioxide and hydrogen sulphide composition respectively 88.53%; 6.33%; and 0.28%. Research conducted by Zhang et al. (2016), the increase in stirring speed does not also bring a high biogas producer. Stirring does not increase CH_4 yield. CH_4 production is not only influenced by stirring but also influenced by the large reduction of COD the greater the reduction of COD, the more CH_4 gas produced (Krishnan et al., 2016). However, according to research conducted Ghamimeh et al. (2012), stirring effect on methane content in biogas production. CH_4 content increases with increasing rate of stirring. CH_4 yield without stirring process was 0.314 L CH_4/gVS, while for 100 rpm stirring obtained 0.3271 L CH_4/mg VS.

Therefore, in the process of methanogenesis in thermophilic conditions with variation of stirring rate, the optimum stirring rate obtained was at 100 rpm, which obtained the highest methane composition value of 88.53%.

IV. Conclusion

Best Biogas Production results obtained at 100 rpm stirring rate, reaching 88.42 L/mg.VS day and Biogas production reached 88.53%, while Volatil solid (VS) reduction reached 20.9038%. Cological citizenship is a new idea that is strived to shape the awareness of citizens in forming a whole human being in the involvement of protecting the environment (Ridwan, 2020).

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