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Biogas Production Under Different Inoculum to Palm Oil Mill Effluent Ratio

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ABSTRACT

Palm oil mill effluent (POME) is a wastewater generated from palm oil industries that rich with organic and nutrients which can becomes an excellent substrate for biogas production. A comprehensive study was carried out to study the effect of different ratio of inoculum to POME substrate for biogas production. In addition, the removal efficiencies of biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (AN), total nitrogen (TN) total suspended solid (TSS), volatile suspended solid (VSS) were also evaluated. Bio-methane potential (BMP) was used by manipulating temperature and HRT which were set to 28-32 °C and 30 days. The BMPs were operated under different ratio of inoculum to substrate at ratio of 20:80, 30:70 and 40:60. Highest cumulative biogas yield obtained was 1990 mL in the BMP containing 30:70 (inoculum:substrate) followed by the ratio of 40:60 with 1055 mL and 20:80 with 345 mL. Maximum TSS and VSS removal efficiency were 27% and 55%, recorded in 30:70 respectively, while in 40:60 and 20:80 were 23% and 12% and 8% and 51% respectively. The removal of TN was also high at 30:70 with 79% removal. Removal efficiency of COD was in BMP of 20:80 with 54% removal while BOD removal was seen the highest in 40:60 ratio BMP. Lastly, the AN were managed to be removed about 95% in 20:80 BMP. The results obtained in this study indicated that with different ratio od inoculum to POME substrate can enhance biogas production and quality of POME prior discharge to environment.

Keywords: POME; inoculum size; methane

INTRODUCTION

According to latest report by Intergovernmental Panel on Climate Change (IPCC), a change in climate is observed in every earth region and across whole climate system (IPCC 2021). Climate change can be defined as abnormality on average weather conditions such as temperature becomes warmer, wetter or drier. It is a trend that differentiates climate changes due to natural weather variability.

This results in world currently is facing greater impact of climate changes sooner than what is predicted by scientists. WHO is expecting that approximately 250 000 additional death due to malaria, malnutrition and diarrhoea caused by climate change between 2030 and 2050 (WHO 2021).

There are many factors that contribute climates change however the major factor is driven by dependency on fossil fuel to derive energy. This is because utilisation of fossil fuel will increase the greenhouse gas (GHG) emission. Reducing GHG through better transport, food and energy use will help in limiting climate change (Ohimain et al. 2017). Due to this, there is increasing interests to shift the fossil fuel derive energy towards low carbon and renewable energy such as biogas.

Biogas is formed during anaerobic digestion of organic matter such as agricultural waste, organic waste material and slaughter house waste (Wronska et al 2018). In general, biogas is made up of mixture of mainly methane (CH_4), carbon dioxide (CO_2), and small quantities of various gas such as hydrogen sulphide (H2S), ammonia (NH4) and nitrogen (N2) (Kumar et al. 2013). Anaerobic digestion is a process where biodegradable materials are decomposed with the absent of oxygen, under certain temperature conditions such as mesophilic or thermophilic and with the presents of different bacteria species such as facultative or achaea. Biogas can be utilised in many ways, either for cooking purpose or source of electricity generation (Indraj Singh 2012).

Palm Oil Mill Effluent (POME) is one of promising substrates for biogas production. POME is a by-product produced in a large volume by many palm oil mills in Malaysia and has become one of major source of pollution (Bala et al 2014). It is estimated that 5 to 7.5 tonnes of water were used to produce one tonne of crude palm oil and more than 50% of the water end up as POME (Chin et al. 2013). This effluent is a thick brownish liquid with high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Besides that, this effluent also contains high solid concentration and also high acidity.

The effluent cannot be directly discharge to water body and must be treated first in order to control water pollution caused by POME. However, the solid content in POME on the other hand might become the good source to generate biogas.

Studies by researchers show that different inoculum to substrates ratio provides positive impact on biogas production and help to reduce potential of the inhibition of anaerobic system (Boulanger et al. 2012).

Hence, this research was conducted to study the effect of POME over inoculum ratio on biogas production and removal performances of certain parameters such as COD, BOD, TSS, VSS, AN and TN.

METHODOLOGY

SOURCE OF POME AND INOCULUM

In this study, both POME and inoculum were obtained from Kilang Sawit Tabung Haji Plantation (THP) Kota Bahagia, Muadzam Shah, Pahang. The POME was collected from raw pond while inoculum was collected from anaerobic pond.

EXPERIMENTAL PROCEDURE

BMP-Test Preparation and Production of Biogas

Biomethane-potential (BMP) test was used to study the effect of substrate/inoculum ratio on production of biogas. The BMP consisted of 1000 ml borosilicate flasks with a screw cap fitted, a gas outlet and connected to eudiometer where it was used to monitor biogas production as shown in figure 1. Three different ratios, 80:20,70:30 and 60:40 of POME: inoculums were selected and a working volume of 750 ml was set in all BMP bottles.

Each of the ratio was triplicated and one BMP bottle was set as control. The temperature was kept constant at 35°C. All BMP bottles then were purged with nitrogen gas for 30 seconds to maintain an anaerobic condition. Gas produced was measured daily using eudiometer for about thirty days. 24 hours prior to test, 50 ml from each of bmp flasks were collected to analyze several parameters such as chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solid (TSS), volatile suspended solid (VSS), ammonia-nitrogen (AN), pH & total nitrogen (TN).

FIGURE 1. Bio-methane potential system

Analytical Methods

Several parameters were analysed by using the standard method provided by HACH company. COD was analysed using high range COD reagent vials with manual code 8000, BOD by using manual method 8043, with incubation period of three days at 30°C, TN by using Persulfate Digestion Method with manual code 10072, AN with manual code 8038. TSS was measured through gravimetric method where samples were filtered, dried and weighed.

Equation 1 below was used to calculate the TSS value. VSS was determined by igniting the sample in the furnace at 550 °C for 15 minutes, cooled and weighed (Abu Hassan et al. 2021). Equation 2 was applied to calculate the VSS content. Lastly, the pH value was analysed using a pH meter.

$$\mathrm{TSS} = \frac{M_1 - M_0}{V} \quad (1)$$

where: M_1 is the final mass of the filter paper (g)
M_0 is the initial mass of the filter paper (g)
V is the volume of the sample (ml)

$$\mathrm{VSS} = \frac{M_2 - M_3}{V} \quad (2)$$

where: M_2 is the mass before ignition (g)
M_3 is the mass after ignition (g)
V is the volume of the sample (ml)

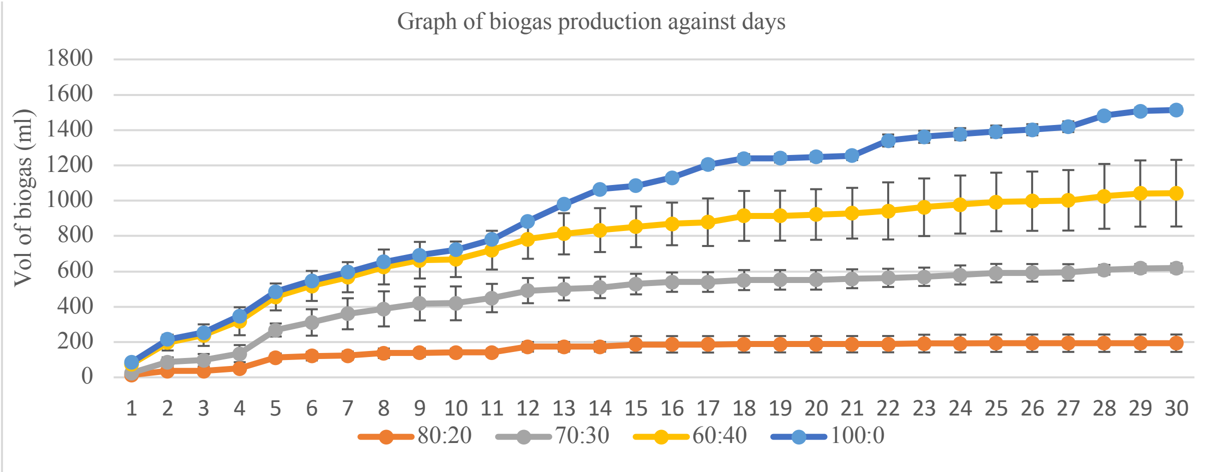

FIGURE 2. Volume of biogas vs days

RESULTS AND DISCUSSION

POME CHARACTERIZATION

All samples were analysed with several parameters such as COD, BOD, TSS, VSS, AN, and TN. Table 1 shows the summarized values of parameters that have been analysed in this study.

TABLE 1. Parameter characterization

Parameters	80:20	std	70:30	std	60:40	std
BOD (mg/l)	2550	-	2663	-	3077	-
COD (mg/l)	57867	94	78600	122	113333	205
TSS (mg/l)	5948	128.46	7075	6.5997	7771	-
VSS (mg/l)	4059	553.52	5525	6.5996	6186	-
AN (mg/l)	1233	47.1404	2400	-	3200	-
TN (mg/l)	67	4.714	157	9.4281	207	9.4281
pH						

PRODUCTION OF BIOGAS

Figure 2 shows the biogas produced for entire four ratios, 80:20, 70:30, 60:40 and 100:0 In this study biogas produced was measured once a day by eudioumeter connected to the BMP bottle based on the volume yield (ml). Based on the result shown, it can be seen that biogas were produced by all ratios except for 80:20 ratio. The highest cumulative biogas production was performed by ratio 100:0, followed by 60:40, 70:30 and lastly 80:20.

Observation after day four shows that biogas yield steadily increased for ratio 100:0, 60:40 and 70:30. One of the reasons is due to the result of acclimitization of methane forming bacteria which indicates that there was substrates utilisation by bacteria (Sidik et al. 2013).

Highest biogas production was by ratio 100:0, followed by 60:40. 70:30 and 80:20. One if the explaination was due to the presence of thermophlic bacteria in the bmp bottles provides high microbial diversity. A study by (Kushkevych et al. 2020) shows that there were presences of thermophile under mesophilic condition in biogas production. This is because POME from raw pond usually contained POME that was newly released from process that has temperature range of 80-90°C (O-Thong et al. 2012). Having large number of species offer potential for failing species to be easily replaced by other species which eventually helps to increase the biogas performance by ratio 100:0 (Westerholm et al. 2019) .

However, biogas produced was relatively low for ratio 80:20. According to the data collected, the cumulative volume of biogas produced for the whole thirty days was under 200 ml. There are several factors might leads to low biogas yield. One of the factors was the result of accumulation of VFA due to low biodegradability which also broughts partial inhibition in the BMP bottle (Budiyono et al. 2018).

The biogas produced after days 30 were 1500 ml, 1200 ml, 600 ml and 200 ml from ratios 100:0, 60:40, 70:30 and 80:20 respectively. From the results obtained, it was found that raw POME appeared to be a good substrate as it produced higher biogas yield. One of the possible explaination was the raw POME contained higher nutrient content (Choong et al 2018). Besides that, the used of POME from different pond also help in producing biogas yield. This is due to the fact that co-digestion help to improve production of biogas.

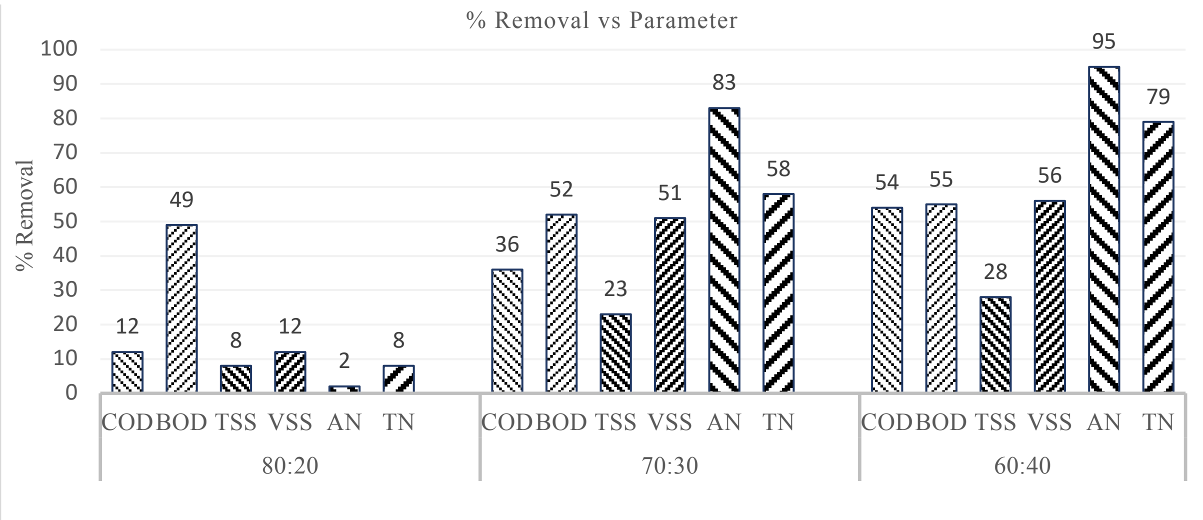

FIGURE 3. Removal vs Parameter

REMOVAL PERFORMANCES

The results of removal efficiency of parameters that were being monitors is shown in figure 3.

Based on the result obtained, ratio 60:40 has the highest percentage of COD removal (54%), followed by 70:30 (36%). While the lowest percentage was achieved of ratio 80:20 with removal efficiency of 12%. Next, ratio 60:40 also achieved highest BOD removal with 54%, ratio 70:30 with 52% and ratio 80:20 with 49%. The decreasing of COD shows that there was an effective anaerobic digestion.

There was no difference for removal of TSS for both ratio 60:40 and 70:30 with 28% and 23% respectively, however the the removal percentage of ratio 80:20 (8%) was very low when compared with other two ratios. The calculated values of VSS shows that highest VSS achieved by 60:40 .

Similar result was obtained in the study by (Aznury et al. 2018), where there was COD reduction in POME after under doing anaerobic digestion with 56%, followed by 70:30 with 51% and 80:20 with 12%. The highest ammonia nitrogen removal was found in ratio 60:40, whereas the lowest ammonia nitrrogen removal was recorded in ratio 80:20 with 2%. Lastly, highest TN removal was also recorded by 60:40 (79%), followed by 70:30 with 58% and lastly TN with 8%.

CONCLUSION

In this study the highest biogas produced recorded was 1500 ml in ratio 60:40. It can be concluded that as the ratio of POME:inoculum increase, the production of biogas will be higher. The highest removal of COD, BOD, TSS, VSS, AN and TN were 54%, 55%, 28%, 56%, 95% and 79%. This study shows that POME can be used as substrate for biogas production.

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DECLARATION OF COMPETING INTEREST

None

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