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Biogas production from POME (Palm Oil Mill Effluent) with the addition of EPOB compost (Empty Palm Oil Bunches)

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Abstract. *Ramadhani GH, Mahajoeno E, Susilowati A. 2020. Biogas production from POME (Palm Oil Mill Effluent) with the addition of EPOB compost (Empty Palm Oil Bunches). Bioteknologi 17: 22-26.* Palm oil mill effluent (POME) is mostly produced by palm oil factories, resulting in environmental pollution. One strategy is by processing waste into a biogas product. The purpose of this research is (i) to make compost from EPOB to produce good compost; (ii) to determine the level of biogas (CH_4) produced from various combinations of POME substrates. Composting was carried out with six treatments. Each treatment consisted of a composition of materials such as EPOB, mushroom seeds [*Volvariella volvacea* (Bulliard ex Fries) Singer], and POME with different concentrations. The method used in composting is the Berkeley method. The mixed material is put in a trash bag and stirred periodically for two weeks in the composting process. The four treatments conducted the experimental design to determine the biogas (CH_4) level. Each treatment consisted of POME, activated sludge, and compost with different concentrations. The process begins with mixing the material into the digester, then every 10th, 20th, and 30th day the gas is taken to measure the CH_4 content. CH_4 levels were obtained by taking gas with a syringe needle on the cover of the digester, then transferred to a flacon bottle. The flacon bottle containing the gas was measured by the Gas Chromatography and Mass Spectroscopy (GCMS) method. The GCMS gas detector is equipped with an FID to detect gas levels and gas type. The results will be displayed in the form of GCMS output and can be seen from the residence time range to determine the type of gas and concentration. The study resulted in the best compost in treatment five, which looks good from a physical point of view, with a 48% water content and 18.25% C/N ratio. The biogas content (CH_4), which produces the highest gas, is 36.206% in treatment 2 (T2) with a composition of 70% POME, 20% activated sludge, and 10% compost.

Keywords: Biogas, compost, empty palm oil bunches, methane, POME (Palm Mill Oil Effluent)

INTRODUCTION

Palm oil is one of the main commodities of Indonesia (Arifiyanto et al., 2017; Faizal and Emdi, 2017). The palm oil industry in Indonesia shows rapid development, resulting in environmental problems. These environmental problems lead to pollution originating from the palm oil industry waste. Palm oil mill waste is very abundant. It is estimated that palm oil mill waste in Indonesia reaches 28.7 million tons of liquid waste/year and 15.2 million tons of solid waste/year (Pardamean 2017).

One type of liquid waste from the palm oil industry is POME (Palm Mill Oil Effluent). In addition, solid waste originating from the palm oil processing process consists of empty oil palm bunches (EPOB), shells, fibers, mud, and cake. One of the solid wastes used in this research is EPOB which is composted and is expected to increase biogas production. The addition of activated carbon helps increase the C/N ratio, improving the anaerobic digestion process and obtaining optimum conditions for CH_4 gas to increase production (Ritonga and Masrukhi 2017). Compost is made with the main raw materials from EPOB, POME, and mushroom [*Volvariella volvacea* (Bulliard ex Fries) Singer] seeds. The addition of edible mushroom seeds belonging to the WRF (White Rotting Fungus) group plays a role in degrading lignin and the main polymers such as cellulose and hemicellulose in EPOB (Nasrul and Maimun 2009).

Anaerobic fermentation to produce biogas is carried out in 4 stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Gijzen 1987). The results of this biogas production can be in the form of gases such as methane (CH_4) (50-75%), CO_2 (25-45%), and small amounts of H_2, N_2, H_2S, CO, H_2O, O_2, dust (Hosseini et al. 2015). This research only focused on producing methane gas using the GCMS gas chromatography method, and it can be seen how much methane gas content is produced. The results of the methane gas produced can later be used for further research on the use of methane gas as alternative energy.

MATERIALS AND METHODS

Research site

This research was conducted in a palm oil mill, namely PT. Swasti Siddhi Amagra, Libo Jaya Village, Kandis Sub-district, Siak District, Riau, Indonesia. Then, continued research in the laboratory located at the factory. The research was carried out in February-March 2019.

Ingredient

This study used the main raw materials in POME, activated sludge, EPOB compost, and *V. volvacea* mushroom seeds obtained from Solo Mushroom, Karanganyar, Central Java, Indonesia. The chemicals used were a solution of H_2SO_4, H_3PO_4, H_3BO_3 4%, HCL, ammonium iron (ii) sulfate, distilled water, NaF solution 4% diphenylamine indicator.

Research design

The experimental design used in this study uses a completely randomized design (CRD) to prove that different substrate compositions produce the best results in producing biogas or methane concentrations. Completely randomized design (CRD) with 4 treatments and 2 replications including control treatment i.e., 100% POME (C), first treatment, i.e., 80% POME, 15% activated sludge and 5% compost (T1), second treatment, i.e., 70% (POME), 20% activated sludge and 10% compost (T2), the third treatment, i.e., 60% (POME), 25% activated sludge and 15% compost (T3).

Procedure

This study uses POME as the main medium for biogas products. The source of inoculum comes from sludge (activated sludge) and the addition of compost. In this study, a simple digester with a volume of 1 liter was used, i.e., 850 mL of the digester volume, which was used as the working volume, and the remaining 15% was used for the air volume.

Composting. Compost was made using the Berkeley method from EPOB fiber, mushroom seeds (*V. volvacea*), and POME with six different treatments. They were put into sacks or trash bags and then covered and perforated. Measurements were made on physical characteristics and temperature on the 3rd, 5th, 7th, 10th, and 14th days. The mature compost after 14 days was measured in water content and C/N ratio. Compost was made into six treatments, namely compost I consisting of 900 grams of EPOB, 0 grams of mushroom seeds, and 270 mL of POME; compost II consisting of 900 grams of EPOB, 30 grams of mushroom seeds, and 270 mL of POME; compost III consisting of 900 grams of EPOB, 60 grams of mushroom seeds, and 270 mL of POME; compost IV consisting of 900 grams of EPOB, 0 grams of mushroom seeds, and 450 mL of POME; compost V consisting of 900 grams of EPOB, 30 grams of mushroom seeds, and 450 mL of POME, and compost VI consisting of 900 grams of EPOB, 60 grams of mushroom seeds, and 450 mL of POME.

The process of inserting materials. The characteristic measurement of POME includes the C/N ratio as a first step to producing good biogas (20-30%). Then insert the material into a simple digester circuit.

Measurement of biogas levels. The gas is taken using a syringe needle and then put into a flacon, then closed with an airtight rubber cover and wrapped in plastic wrap. Gas samples were measured using the gas chromatography method with a GCMS device equipped with FID as a detection sensor. The gas that has been detected can be seen on the monitor in the form of an output containing peak, area, and residence time to find out what type of gas and what concentration.

RESULTS AND DISCUSSION

EPOB compost results

Composting that has been carried out for 14 days can be seen in terms of physical characteristics, C/N ratio, and water content according to SNI. From the six compost treatments, the best compost is selected. The best compost will be selected as an additional substrate for making biogas. The compost results on the 14th day can be seen in Table 1.

Based on SNI 19-7030-2004, mature compost, in terms of physical characteristics, has an earthy odor (odorless), dark brown, easy to crush, and a temperature similar to groundwater (about 25-29°C). Meanwhile, the C/N ratio is 10-20%, and the water content does not exceed 50%. It can be concluded that the compost, according to SNI, is compost V. Compost V is categorized as the best compost and is used to add substrate for biogas production). Compost V showed a faster temperature increase than other composts from day 3rd to day 7th, around 29-40°C. The increasing temperature results in the development of thermophilic bodies known to have the ability to remodel recalcitrant compounds such as lignin. Then the temperature decreases again, and the composting process enters the maturation phase (Strom 1985).

Table 1. The physical character of compost on day 14th

Compost	Physical character	Temperature (°C)	C-Organic	Total N	Water content
I	Musty smell, not easy to crumble, light brown	35	35,67%	1,48	58%
II	Musty smell, not easy to crumble, brown	31	35,00	1,55	54.2%
III	Smells like earthy odor, crumbles easily, dark brown	28	32,02	2,00	58%
IV	Musty smell, not easy to crumble, light brown	33	27,56	1,50	51.8%
V	Earthy odor, crumbles easily, dark brown	29	26,62	1,46	45%
VI	Earthy odor, not easy to crumble	34	25,13	1,55	46.4%

The C/N ratio in Table 1 indicates that compost containing white-rot fungus media (*V. volvacea*) at a concentration of 60 grams in compost III and VI can effectively reduce the C/N ratio, as Nasrul and Maimun (2009) stated that the effect of adding white-rot fungi causes the C/N ratio to decrease more rapidly, indicating that the composting process was proceeding normally, show by the decomposition of organic materials into compost with a low C/N ratio. The use of edible mushroom (*V. volvacea*), which belongs to the white-rot fungus (WRF) division of Basidiomycetes, could produce ligninolytic enzymes extracellularly that would degrade and reduce lignin levels (Kaal et al. 1995).

Compost IV that was not given with white-rot fungi could reduce the C/N ratio even though the ratio of C/N produced was not as low as that of compost V and VI, which were given with mushrooms. It may be because the addition of mushrooms was less influential. After all, the composition of POME was too much, namely 450 mL, and in its contents, some microorganisms play a role in decomposing cellulose in the EPOB composting process, namely *Bacillus* sp. and the genus *Aspergillus* (Rajagukguk 2018). Although compost IV, in terms of the C/N ratio, is per SNI, in terms of physical characteristics, it does not guarantee that compost IV is ripe because of the smell, which is still very pungent and musty. The condition of the compost is still moist.

Biogas production and methane concentration

The process of biogas formation in the anaerobic fermentation of organic matter is carried out by the microorganism Archaea methanogens to produce combustible gas because it contains methane (CH_4). The reshuffle process was carried out using a simple digester on a laboratory scale for 30 days of observation time, and data were taken every 0^{th}, 10^{th}, 20^{th}, and 30^{th} day. The average volume of biogas is presented in Figures 1 and 2.

Figure 1 has an increase in volume between treatments in producing biogas. The variation of the biochemical properties of the substrate causes the biogas production also to vary (Irvan et al., 2012). Several organic materials can be used together with some suitable gas production or normal growth requirements of methane bacteria. Some of the properties of these organic materials have a significant impact on the gas production rate. The increase in biogas volume is due to the different substrates of each treatment. Treatment 2 (T2) had a higher increase on day 30^{th} than other treatments, i.e., 593 mL. It was in line with the methane formation, i.e., 36.21%. The organic matter with a concentration equal to the inoculum degrades faster. It facilitates the diffusion of dissolved materials, resulting in faster gas formation. Mahajoeno et al. (2008) research revealed that a 20% concentration of activated sludge inoculum with 15 liters of substrate produced the most gas compared to other concentrations. In addition to the volume of biogas formed, the methane concentration results after being tested by GCMS gas chromatography can determine the content of methane gas. The following is a graph of the concentration of methane gas presented in Figure 2.

The methane gas produced is also not too large, only 36.21% at T2. In this study, only a small-scale digester was used, temperature stability was not maintained, and periodic shaking was not carried out. However, in Sarono et al.'s (2016) research, the concentration of methane gas from the main ingredient POME produced by high-temperature treatment of 55ºC could produce a methane concentration of 65.44%. Data on biogas volume and methane concentration were also statistically tested with SPSS using GLM repeated measures independently. Hypothesis testing was used to determine whether there was a significant difference in the volume of biogas and methane concentration on the 10^{th}, 20^{th}, and 30^{th} days of extraction. The hypothesis testing was carried out to determine whether there was a statistically significant difference on the 10^{th}, 20^{th}, and 30^{th} day of extraction and obtained a sig value of 0.02 for the volume of biogas and 0.014 for the concentration of methane. Because the sig value was less than 0.05, it was concluded that the data of biogas volume and methane concentration with extraction time on the 10^{th}, 20^{th}, and 30^{th} days are statistically significant differences.

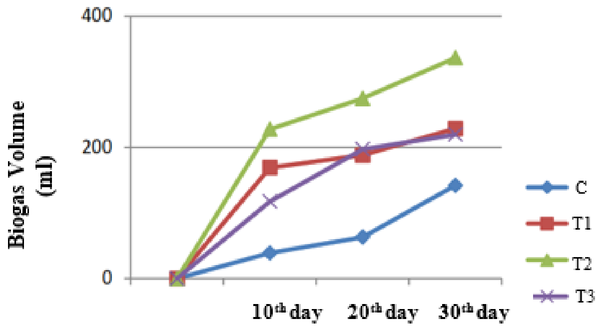

Figure 1. Volume of biogas formed up to day 30^{th}. C: 100% POME; T1: POME 80% + Activated sludge 15% + Compost 5%; T2: POME 70% + Activated sludge 20% + Compost 10%; T3 POME 60% + Activated sludge 25% + Compost 15%

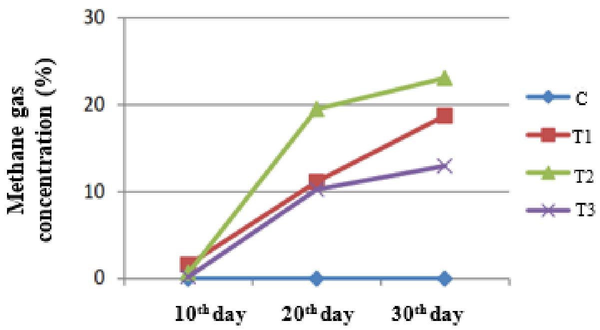

Figure 2. Concentration of methane formed up to day 30^{th}. K: 100% POME; T1: POME 80% + Activated sludge 15% + Compost 5%; T2: POME 70% + Activated sludge 20% + Compost 10%; T3 POME 60% + Activated sludge 25% + Compost 15%

COD and BOD concentration

The Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) values are important parameters determining the overhaul or degradation of waste organic matter. The effect of the substrate concentration can also affect the value of COD and BOD resulting from the process of overhauling organic matter in the waste. The COD values are presented on average in Figure 3.

The decrease in COD value is due to the hydrolysis process, organic material being remodeled as nutrients for organisms and then converted into simpler compounds (Kresnawaty 2008). The highest COD reduction or reduction occurred on days 10th to 30th, 17.60% in T2. The lowest occurred on days 0th to 10th, 0.25% in the control treatment (C). The resulting BOD value is also shown in the decrease in the BOD value in Figure 4.

The highest degradation efficiency value of BOD reduction was 5.95% in T2, and the lowest was 0.15% in the control treatment. It shows that microorganisms that work optimally degrade because the longer residence time provides a longer contact opportunity between the substrates; thus, the degradation efficiency process is better than at other times. There was no inoculum in the form of activated sludge in the control treatment, a source of microorganisms that can help break down organic material into simple molecules. Based on COD and BOD data. The longer the residence time will increase the efficiency of the degradation itself. The longer the contact time between organic waste and biomass, the degradation process of organic pollutants can last longer and make the substrate COD and BOD concentration lower (Munazah and Soewando 2008). An increasingly alkaline pH value can cause the efficiency of COD and BOD degradation to decrease in efficiency in several treatments, which makes the decomposition process not reach the perfect methanogenic stage. At this stage, there is a process of reshuffling organic matter into acid, then acetic acid, and forming methane gas (CH_4), resulting in a decrease in COD and BOD values (Adekunle and Okolie 2015).

TS and VS concentrations

Changes in the properties of waste can also be seen from changes in Total Solid (TS) and Volatile Solid (VS) values. The decreasing value of TS and VS means that microorganisms carry out the decomposition of organic matter. The TS value is seen in Figure 5.

The Total Solid value in T3 has a higher concentration than in other treatments. It is due to the concentration of the substrate being too dense or the organic material in so much quantity. Still, overall, the TS value has decreased due to the degradation process carried out by microorganisms. In addition, the value of VS is also presented in Figure 6.

Total solid and final solid volatile indicate a decline in value, although not so drastically. It is due to the decomposition process of the material by decomposing bacteria. This decrease indicates an increase in the levels of methane gas produced. The decrease in VS shows the degradation of organic compounds by non-methanogenic microorganisms (Yahya et al., 2017).

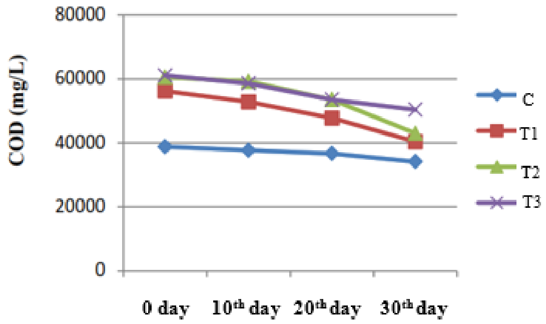

Figure 3. COD values formed up to day 30th. C: 100% POME; T1: POME 80% + Activated sludge 15% + Compost 5%; T2: POME 70% + Activated sludge 20% + Compost 10%; P3POME 60% + Activated sludge 25% + Compost 15%

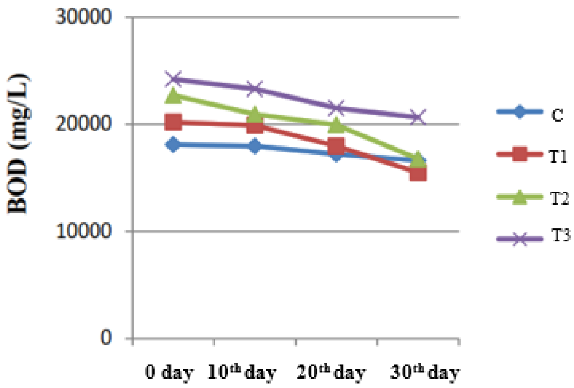

Figure 4. BOD values formed up to day 30th. C: 100% POME; T1: POME 80% + Activated sludge 15% + Compost 5%; T2: POME 70% + Activated sludge 20% + Compost 10%; T3 POME 60% + Activated sludge 25% + Compost 15%

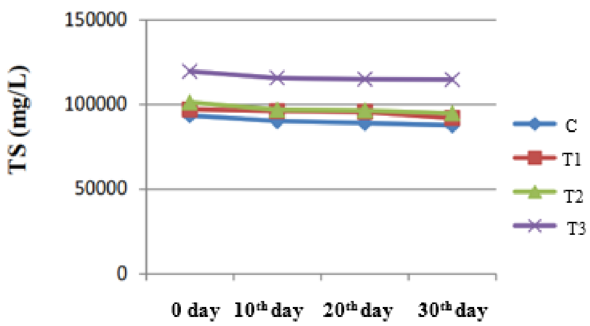

Figure 5. TS values formed up to day 30th. C: 100% POME; T1: POME 80% + Activated sludge 15% + Compost 5%; T2: POME 70% + Activated sludge 20% + Compost 10%; T3 POME 60% + Activated sludge 25% + Compost 15%

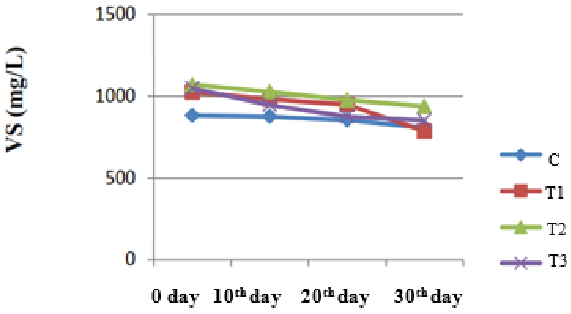

Figure 6. VS values formed up to day 30th. C: 100% POME; T1: POME 80% + Activated sludge 15% + Compost 5%; T2: POME 70% + Activated sludge 20% + Compost 10%; T3 POME 60% + Activated sludge 25% + Compost 15%

Concentration, temperature, and pH

At the beginning of the study, the pH tended to be acidic in each treatment. On the 10th to 30th day, the pH continued to increase. The highest pH was 6.82 in treatment 2 (T2). Increasing pH can accelerate the decomposition process, thereby accelerating the overhaul and indirectly accelerating biogas production (Metcalf and Eddy 2003). The increase in pH that occurs is one of the processes of biogas formation. Microorganisms continue to break down organic matter so that the pH increases (acid pH is close to neutral), thus increasing the pH to neutral conditions that are good for biogas production. A lot of biogas production is produced. The optimum pH for methanogenic bacteria or methane-producing bacteria is acid, which tends to be neutral, around 6.8-7.5 (Shah et al. 2014). The temperature obtained from day 0th of 57th OC shows the actual temperature of the POME itself, which is hot. This research does not use temperature variations, decreasing due to room temperature.

In conclusion, According to SNI, the fifth compost (V) is the best compost, with a C/N ratio of 18.35%. The volume of biogas produced is 593 ml. It is in line with the methane gas formed through the GCMS Gas chromatography technique, producing 36.21% methane gas in treatment 2 (T2). Meanwhile, for COD values of 17.60% and BOD 5.95%, which experienced the highest degradation efficiency in treatment 2, a high level of COD BOD reduction would result in a large amount of gas accumulation. The highest TS reduction value of 6.52% and VS 23.90% also occurred in treatment 2. This decrease indicated an increase in methane gas content; as evidenced in this study, the highest biogas volume and methane concentration were obtained in treatment 2.

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