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Evaluation of COD Removal using Dielectric Barrier Discharge to Produce Biogas from POME

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Abstract. Evaluation of Chemical Oxygen Demand (COD) removal by a dielectric barrier discharge (DBD) system to produce biogas from palm oil mill effluent (POME) was investigated in a batch experiment. The residence time was set at 1 hour. The batch experiments were observed with voltage variation at 10, 15, 20 and 25 kV. It was found that the COD removal was measured at 22.47% to 44.94% with the applied voltage was set at 10-25 kV, respectively. The results also shown that the maximum yields of hydrogen and methane by the system were 7.94 and 1.78 mL/mL of POME, respectively that were obtained at an applied voltage of 25 kV.

1. Introduction

Palm oil industry in Indonesia is the biggest producer in the world [1]. As consequence, it also produces large quantities of POME during crude palm oil (CPO) processes. Each ton of CPO produces about 3 tons of POME [2], which is considered wastewater. POME wastewater can cause serious water pollution because it contains high levels of organic contents such as high chemical oxygen demand (COD), biochemical oxygen demand (BOD), total dissolved solids (TDS) and oil-grease. Conventional methods mostly used for the treatment of POME to produce biogas used in the palm oil industry are: open ponding, anaerobic and aerobic systems, or combinations of both. The advantage of these methods is that biological treatment is easy, but disadvantages are that they require a long hydraulic retention time (HRT) and a large area of land [3-4]. Also, POME wastewater treated in open ponds can cause great amounts of greenhouse gas emission. However, there is an opportunity to convert POME wastewater into biogases such as hydrogen and methane. POME wastewater is a very promising source for renewable energy. Each ton of POME can produce about 28 m³ of biogas [5]. It has been reported that the treatment of POME to produce biogas requires from 1 to 10 days, respectively [6-7].

Since recently it is known that POME can be treated successfully using a dielectric barrier discharge (DBD) plasma system. This system is able to reduce the HRT for treatment of COD, BOD and oil-grease to achieve standard wastewater quality and to produce biogas simultaneously [8]. Our previous results also resulted that the maximum yields of hydrogen at 2.42 mL H₂/mL POME and methane at 1.32 mL CH₄/mL POME. Based on our previous studies [8-9], modification design of DBD plasma reactor is very important to increase the hydrogen production.

The purpose of this work is to study the performance of DBD plasma reactor to increase production of H₂ from POME. The DBD plasma system generates a oxidize radicals (H· and ·OH) and molecules (H₂O₂, O₃, etc.) to accelerate the chemical reaction. These chemical reactants are very effective in decomposing organic compounds in wastewater [10-11].



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2. Material and Methods

The characteristic of POME used in this study is shown in Table 1. The POME was taken after the fat-grease pit from a wastewater treatment system in the palm oil industry. The experimental setup for biogas production is displayed in Figure 1. This experiment used a needle-plane electrode configuration system with a separation between the needle and the POME surface of 5 mm. A stainless steel needle electrode and a plane electrode were used, with a diameter of 3 mm and a thickness of 1 mm. The upper needle electrodes and a lower plane electrode were connected to a high voltage system with a frequency of 50 Hz. The applied voltages and discharge currents were measured through a high voltage probe (P6015A Tektronix) and a current probe (P6022 Tektronix), and recorded by an oscilloscope (TDS5104 Tektronix). The applied voltages were varied at 10, 15, 20 and 25 kV. Furthermore, a container glass with a storage volume of about 3500 mL was used as the DBD reactor. The volume of the POME in the DBD reactor glass was 1000 mL. In addition, a smaller container with a storage volume of about 1500 mL was used as gas storage. The accumulated hydrogen and methane gas were detected by commercial MQ8 and MQ4 gas sensors (Hanwei), respectively. All gas sensors were connected to a data logger (ADC24 Pico) to digitize and record the conductivity change related to the electrical output signal of gas concentrations in the storage container every second for one hour, which was controlled by a personal computer (PC). Figure 2 shows the applied voltage to generate the discharge current in the DBD reactor.

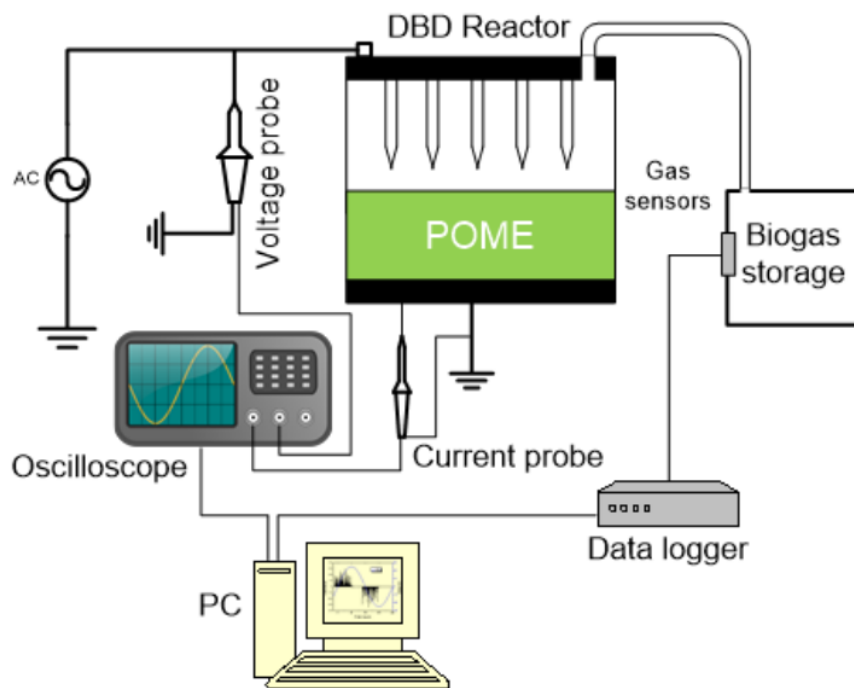


Figure 1. The experimental setup system.

Table 1. Characteristics of POME.

Parameter	Unit	Value
COD	mg/L	5520
BOD	mg/L	2000
pH		4.2

3. Results and Discussion

The experiment studied the effects of applied voltage and time on the discharge current in the DBD reactor and the product yield in the biogas storage. The applied voltage and the discharge current in the DBD reactor were measured and recorded by oscilloscope through high voltage and current probes, while the biogas product yield in the storage detected by the gas sensors was recorded by a data logger.

3.1 Discharge current characteristic

Figure 2 shows that the discharge current pulse train occurred at an applied voltage of 20 kV. The discharge current arose around the peaks of both the positive and the negative half cycles for the applied voltage as can be seen in Figure 2. The discharge current on the POME surface produced UV light and various active species with high oxidation potential ions and molecules such as ozone (O_3), perhydroxyl radical ($\cdot OH$), hydroxyl radical ($\cdot OH$) and hydrogen peroxide (H_2O_2), which effectively decompose organic compounds. The decomposition process of POME produces water, inorganic salts [11] and biogases such as hydrogen (H_2), methane (CH_4) and carbon monoxide (CO).

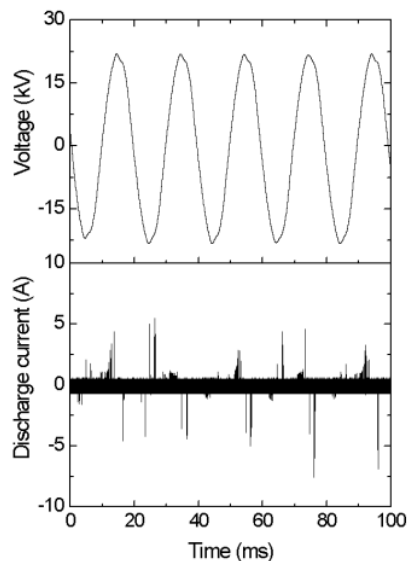


Figure 2. Typical the voltage application and the discharge current.

3.2 The effects of applied voltage on biogas production

The removal efficiency (RE) of chemical oxygen demand (COD) in the DBD system is shown in Figure 3a. The removal of COD was measured at 22.47%, 30.34%, 33.71% and 44.94% with the applied voltage was set at 10, 15, 20 and 25 kV in a batch experiment for 1 hour. These results are similar with our previous study [8] found that the removal efficiency of COD was 31% with applied voltage at 19 kV. Based on the results in [9], the decrease of COD was observed by formation of biogas such as

hydrogen and methane. It was found that the degradation rate of POME increased with an increased voltage. The effects of the applied voltage on the yield production of biogas is displayed in Figure 3b. The yield of hydrogen increased from 5.32, 6.30, 7.22 and 7.94 mL H₂/mL POME after 1 hour with the applied voltage at 10, 15, 20 and 25 kV, respectively.

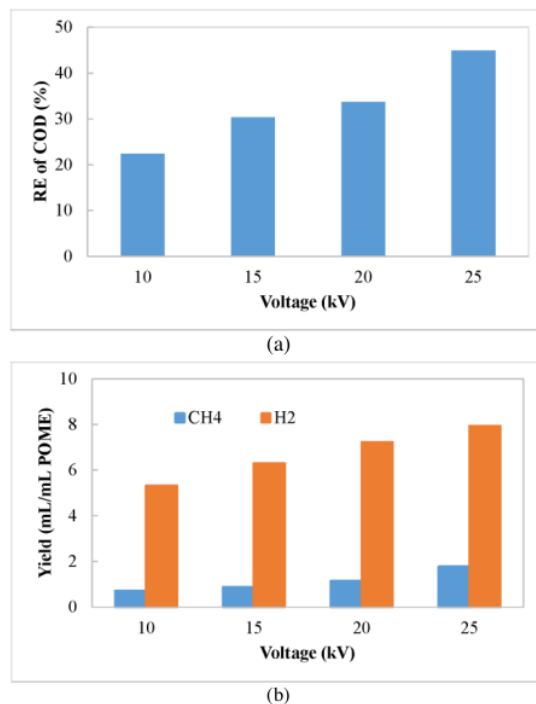


Figure 3 (a). The effects of applied voltage on removal efficiency of COD. **(b).** The effects of voltage application on yield production of hydrogen and methane.

Figure 3 also shows that the yield of methane increased from 0.71, 0.88, 1.15 and 1.78 mL CH₄/mL POME after 1 hour with the applied voltage at 10, 15, 20 and 25 kV, respectively. Norfadilah et al [7] found that the biogas production contained 5.99 mL H₂/mL POME after 10 days fermentation process. The biogas contained with 36% H₂ and 64 % CO₂. The biogas production using fermentation process depends on the substrate and microorganism concentration, pH, temperature and hydraulic retention time to produce biogas following hydrolysis, acidogenesis and methanogenesis [12-13]. Latief et al [14] investigated biogas production from POME and found that when the biogas contains 63% methane with processing time at 25 days, the system should be well controlled under mesophilic condition (37 °C). The processing time in the present study was 238 times faster compared with the results using fermentation. The biogas production with DBD system consisted of 82-88% hydrogen and 12-18% methane. These results were higher than our previous studies [8-9] before modification of DBD plasma reactor.

4. Conclusion

The effects of applied voltage on biogas production from POME was studied using a DBD plasma system. It was found that increasing the applied voltage caused an increase in the yield of hydrogen and methane. The highest hydrogen and methane yields were 88% and 12%, respectively with the applied voltage at 25 kV in batch experiment for 1 hour. The processing time in the present study was 238 times

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