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# The Input Voltage and Reaction Time from Dielectric Barrier Discharge Treatment Affect the Biogas Production and the Reduction of Pollutants in Palm Oil Mill Effluent

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**Abstract.** The performance of dielectric barrier discharge (DBD) treatment was investigated to demonstrate the potential use for palm oil mill effluent (POME) treatment in terms of biogas production and chemical oxygen demand (COD) and total solids (TS) reduction. The treatment was undergone by applying the different input voltage of 15, 20 and 25 kV for 3 hours of reaction time with a frequency of 50 Hz in a DBD glass reactor. The experiment was carried out at room temperature and under normal air pressure. The results showed that the biogas concentration increased with the increase of input voltage. The concentration of hydrogen, methane, carbon monoxide and carbon dioxide increased from the initial values by 85%, 10%, 33% and 99%, respectively, for the input voltage of 15 kV. Biogas concentration also increased with the prolonged reaction time, indicated that more energy was supplied to convert the organic pollutants to form biogas. The high reduction of pollutants in POME was achieved to 48% for COD and 42% for TS when the applied voltage increased to 25 kV. The low reduction of COD and TS was probably caused by the high pH value of POME used in this study, resulting a poor degradation and agglomeration of COD and TS.

## INTRODUCTION

Indonesia is the world's top producer and exporter of palm oil with the production of the commodity amounted to around 48.4 million metric tons (Badan Pusat Statistik, 2020). In recent years, the production of palm oil had come under increased global scrutiny and criticism, due to detrimental effects on the environment. Along with the production of palm oil, palm oil mills generate large volumes of effluent from palm fruit extraction, in hereafter refers as palm oil mill effluent (POME). POME is considered as a high strength industrial wastewater which can be 100 times more polluting than municipal sewage (Wu et al., 2008). POME contains about 95–96% of water, 4–5% total solids (TS) and was also reported to have high biological oxygen demand (BOD), chemical oxygen demand (COD) and the presence of organic acids with unpleasant odor (Anuar et al., 2021). Furthermore, Mao et al. (2018) reported that 28 m<sup>3</sup> of methane was produced per ton of POME. POME is a prospective source for biogas production as an alternative renewable energy source (Desmiarti et al., 2021). Thus, sustainable treatment for POME produced from oil palm mills is required for safe disposal to the environment.

Numerous conventional treatments have addressed to be used for POME treatment, such as biological treatment (Rahman et al., 2018), coagulation and flocculation (Zahrim et al., 2017) and electrocoagulation (Ibrahim et al., 2018; Moussa et al., 2017). Pond treatment is widely used for POME treatment that consists of anaerobic, facultative, and aerobic systems. However, pond treatment is incapable to achieve satisfactory effluent quality due to ineffective pollutant degradation, high operating on aeration energy and pond desludging, polluting the receiving

watercourses, as well as the emissions of gases (Show et al., 2021). Advanced treatments appear to be most favorable for degradation of highly concentrated organic pollutants in POME. For lab-scale, the use of dielectric barrier discharge (DBD) had demonstrated that organic pollutant could be removed as well as the successful production of biogas from POME (Desmiarti et al., 2021). DBD generates the oxidant agent, such as hydroxyl radicals ( $\bullet\text{OH}$ ), hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) and ozone ( $\text{O}_3$ ), which have a high oxidation potential to decompose organic compounds in water (Budiman and Wu, 2016; Hazmi et al., 2017). With different input energy and the presence of oxidant agents, the higher conversion, and the degradation of organic pollutants to form biogas in POME could be achieved through DBD treatment. To improve treatment efficacy, this study investigates the feasibility of DBD system to produce gas from POME by reducing the reaction time.

In this study, DBD reactor was equipped with the real time gas sensor with high sensitivity and detection limit to record the biogas produced from POME. The input voltage of 15, 20 and 25 kV and reaction time for 3 hours were identified for the experiment. This work can be used to diagnose the optimum conditions for biogas formation from POME in lab-scale. The aim of this study is to investigate the performance of DBD treatment by varying the input voltage and reaction time for biogas production from POME as well as the reduction potential for pollutants in POME assessed by COD and TS values.

## MATERIALS AND METHODS

### POME

The POME used in this study was purchased from Tranco Energi Utama Incasi Raya Group, a palm oil company located in Indrapura, West Sumatra, Indonesia. The POME was collected from the initial sedimentation tank, and the filtration was performed to remove dirt, plant cell debris, fibers, and other solids. The initial COD, TS and pH were 2866.2 mg/L, 456.9 mg/L, and 5.5, respectively. The proximate compositions of POME are shown in Table 1 (Salihu and Alam, 2012).

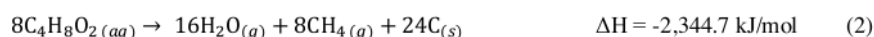
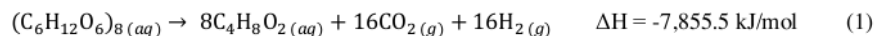
**TABLE 1.** The proximate compositions of POME

Components	Composition (%)
Moisture	6.99 ± 0.14
Crude protein	12.8 ± 1.30
Crude lipid	10.2 ± 1.24
Ash	14.9 ± 1.35
Carbohydrate	29.6 ± 2.44
Nitrogen free extract	26.4 ± 2.33
Total carotene	0.02 ± 0.00

### DBD Treatment

A 3,500 mL glass was used as a DBD reactor and the working volume of POME was 800 mL. The system was operated at room temperature (25°C) and atmospheric pressure (1 atm) following by Desmiarti et., al, 2021. DBD system was equipped with a needle-plane electrode, with the needle electrodes was connected to a high voltage alternating current with a frequency of 50 Hz, while the plane electrode was connected to the ground. The input voltages used in this study were 15, 20 and 25 kV, were supplied to the AC source with the reaction time of 3 hours, and were recorded with a P6014A Tektronix high-voltage probe. The discharge currents were recorded using a TDS5104 oscilloscope through a P6021A current probe. A diaphragm pump was used to flow the gas from DBD reactor to an acrylic gas storage with the volume of 800 mL.

The degradation of organic pollutants in POME will create biogas, where carbohydrates are used as substrates for the following reactions.



## Analysis

A TGS 821, TGS 816, and CDM 7160 manufactured by Figaro Ltd., Japan was used to record the concentration of H<sub>2</sub>, CH<sub>4</sub>, and CO and CO<sub>2</sub> gas, respectively. A Pico ADC24 data logger was used to record the gas concentration for 3 hours reaction and transfer the electrical output signals to a personal computer. The pH, COD and TS were measured with the procedures described in the APHA standard methods.

## RESULTS AND DISCUSSION

### Biogas Production under Different Input Voltage

Fig. 1 shows the amount of biogas produced from POME with the variation of input voltage. DBD treatment generates the oxidant agents when the high voltage was applied and react with organic molecules in POME to form H<sub>2</sub>, CH<sub>4</sub>, CO, and CO<sub>2</sub>. When the input voltage was increased to 25 kV, H<sub>2</sub> and CO concentration increased by 82% and 8%, respectively. The applied voltage could facilitate the energy absorption by C=O in CO<sub>2</sub> to form CO. The high concentration of H<sub>2</sub> was thought that DBD treatment accelerated the formation of •O from C=O that will react with CH<sub>4</sub> and form H<sub>2</sub> (Mao et al. 2018). The increase of biogas production with the increase of input voltage indicates a high reaction of biodegradable substances in POME with oxidant agents produced from DBD treatment. Supplying a higher input voltage will enhance the concentration of oxidant agents and electron density, thus promote high conversion of CH<sub>4</sub> and CO<sub>2</sub>.

The formation of biogas generally increased with the increase of reaction time. H<sub>2</sub> and CO concentrations are show the increase trend for applied voltage of 15 kV up to 86% and 10% at 15 kV, respectively. CO<sub>2</sub> and CH<sub>4</sub> show a stable trend of concentration with the prolonged reaction time. This indicates that the formation of CO<sub>2</sub> and CH<sub>4</sub> for higher applied voltage reached a maximum conversion due to limitation of energy density. Generally, prolonged reaction time can supply more energy consumption for biogas in DBD reactor, thus increasing the biogas production (Mao et al., 2018).

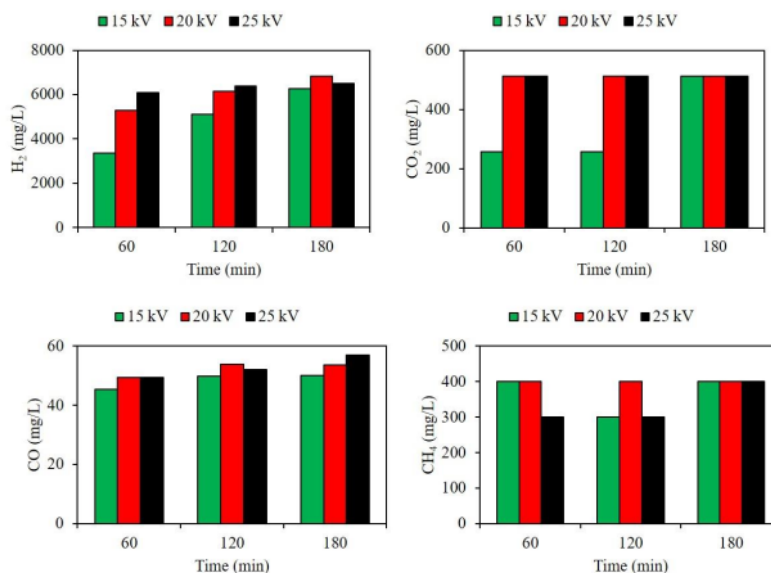
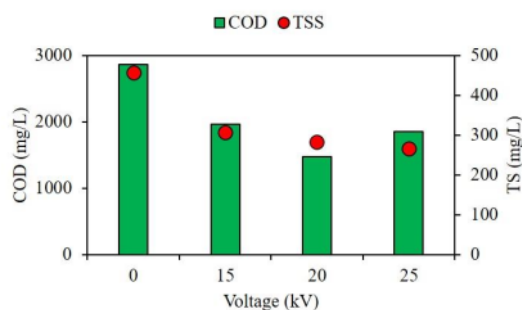


FIGURE 1. The amount of biogas produced from POME with different input voltage.

## Effect of Input Voltage on the Reduction of COD and TS



**FIGURE 2.** The amount of (a) H<sub>2</sub>, (b) CO<sub>2</sub>, (c) CO and (d) CH<sub>4</sub> produced from POME with different input voltage.

Besides enhance the production of biogas, DBD treatment can facilitate the biodegradation of POME by the reduction value of COD and TS. Fig. 2 shows the reduction amounts of COD and TS by adopting a different input voltage. The greatest percentage reduction of COD was observed at 20 kV, which corresponded to 49%, while TS reduction was observed higher for up to 42% at 25 kV. The lesser reduction of COD at 25 kV was probably due to the presence of high recalcitrant organic substances in POME that was not be able to react with oxidant agents during DBD treatment. However, the reduction of COD and TS in this study are generally lower to that corresponding study by Liew et al. (2021), where COD and TS removal was achieved for 88.9% and 61.5%, respectively. This may be due to the lower settle-ability and biodegradability of the POME used in this study.

The DBD treatment demonstrates the COD and TS reduction in POME by adopting a higher input voltage and electricity (Desmiarti et al., 2021). During DBD treatment, •OH generated and attacked the organic substances in POME and initiated the oxidation destruction through radical addition and directly reduced COD content (Taha and Ibrahim, 2014). DBD treatment also can precipitate the lignin content in POME and reduced the pH value, resulting a reduction in TS and pH dropped from 5.5 to 5. As the pH recorded as 5 at 25 kV, the result shows that lower pH can cause the agglomeration of lignin particles to form bigger and denser flocs, thus resulting lower TS value. This finding is concordant with a study by Taha and Ibrahim (2014) which showed that pH 2 accelerated the agglomeration of particles in POME, resulting lowest turbidity.

## CONCLUSION

The input voltage and reaction time applied in DBD treatment were investigated to observe the potential production of biogas from POME as well as the reduction of COD and TS. Increasing the input voltage enhanced the conversion of POME to form H<sub>2</sub>, CH<sub>4</sub>, CO and CO<sub>2</sub> gas by DBD treatment for up to 86%, 33%, 10% and 99%, respectively. Reaction time also affects the production of biogas from POME. Increasing the reaction time when the voltage was 25 kV, biogas concentration increased to 7%, 33% and 16% for H<sub>2</sub>, CH<sub>4</sub> and CO. COD and TS decreased with the increased of input voltage. The high reduction number of COD observed at 20 kV which corresponded to 49%, while TS reduction was observed 42% at 25 kV. The low reduction of pollutants in this study were likely to be caused by the high pH value of POME that could not facilitate a good performance of degradation of COD and agglomeration of TS. However, the current operational performance of this study needs further investigation (i.e., pH adjustment as pretreatment process). Decreasing pH value can accelerate the degradation process as well agglomeration process, resulting high reduction of COD and TS. This work provides the important information on understanding the DBD treatment system to the wastewater conservation and treatment, POME in particularly.

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