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The Performance of Electricity Producing of Dual Chamber Microbial Fuel Cells (MFCs) Using Wastewater of Tempe Industries

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Abstract. *Luthfiah Y, Artsanti P. 2017. The Performance of Electricity Producing of Dual Chamber Microbial Fuel Cells (MFCs) Using Wastewater of Tempe Industries. Proc Internat Conf Sci Engin 1: 153-156.* The performance of electricity producing of Dual Chamber Microbial Fuel Cells (MFCs) using wastewater of tempe industries without glucose addition (as control substrate) and with (2% and 4%) glucose addition was observed. The anode chamber contained a waste substrate and a cathode chamber contained a 0.1 M Potassium Permanganate electrolyte solution. The salt bridge was required to stabilize the charge between the cathode and anode chambers, and the electrodes attached to the anode and cathode chambers as the electron catcher. Voltages and currents were measured using multimeter. Optical Density measured at 486 nm wavelengths was performed to estimate bacterial growth activity. All of the cells were observed for 72 hours of running time. The results of Optical Density curves showed an increasing trend of absorbance during 72 hours of running time. These were in agreement with the resulting power density, which tended to increase until the 48th hour and then relatively stable especially for the substrate with 4% glucose addition. These MFCs system could also reduce COD by 1.52%, 9.76%, and 9.64% on control substrate, 2% glucose addition substrate, and 4% glucose addition substrate, respectively.

Keywords: Microbial Fuel Cell, Tempe Wastewater, Power Density, Optical Density, Chemical Oxygen Demand, Glucose

INTRODUCTION

In this year the challange of the human society is facing is to meet the ever increasing demand for different energy sources, which are getting exhausted. Microbial Fuiel Cell is one of the best alternative sources of energy production, especially electricity which add wastewater to the list of reneweble resources of energy.

Microbial Fuel Cells (MFCs) is a system that converts chemical energy into electrical energy that use of bacteria. Organic and or inorganic materials are used as an energy source for bacterial metabolism. Bacteria can be used in MFC systems to generate electrical energy while completing the process of destruction of organic material (Du, 2007). The rest of the bacterial metabolism in the form of electrons will flow in the system to produce electricity (Logan et al., 2006).

Microbial Fuel Cells (MFCs) is a system or tool that uses bacteria as a catalyst to oxidize organic and inorganic materials. The electrons are produced by bacteria from the substrate which are then transferred to the anode (negative pole) and flow from the cathode (positive pole) connected by the conductivity device including the resistor, or operated under the charge to produce a power that can run the appliance. The positive of the current meter flows from the positive pole to negative, the opposite direction to the electron flow (Logan et al., 2006).

Bacteria attach to the anode that oxidizes the organic substrate and release electrons and protons. Protons in the chamber anode move through the membrane to the chamber cathode, when the electrons leas from the bacteria to the electrodes (anodes) on the same chamber and then through the circuit to the cathode where they coalesce with the protons and oxygen to form water. In this way electricity can be produced. Other chemicals such as nitrate, sulphate, and manganese can be used as proton acceptor. (Zhang, 2012).

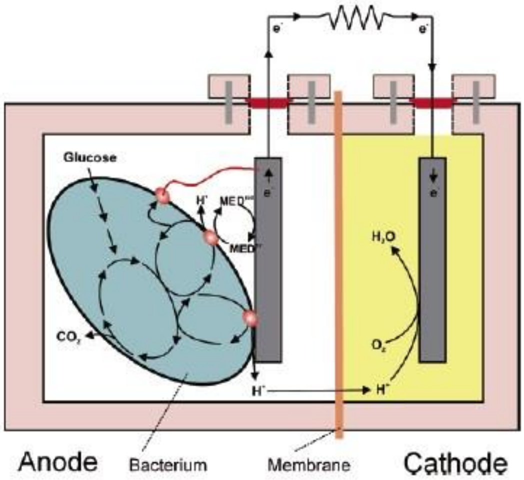
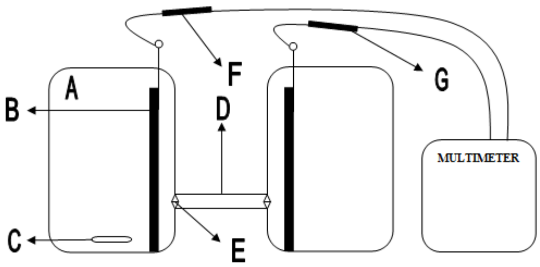


Figure 1. Operating Principle of Microbial Fuel Cell (Logan, 2006).

The use of organic liquid waste as well as degradation of organic compounds in it that makes the application of this MFC system is considered more environmentally friendly (Li, 2010). Wastewaters that are rich in organic matters are all great biomass sources for MFCs, such as wastewater of textile industries and wastewater of tempe industries (Kirana, E.F., 2017; Utami et. al., 2014). The wastewater of tempe used in this study is taken from home industry of tempe processor in Banguntapan, Bantul, Yogyakarta.

MATERIALS AND METHODS

The MFCs tool in this study uses electrochemical cells with dual chamber system consisting of cathode and anode compartments, using three reactors with 2000 mL reactor capacity. The electrolyte solution used was a solution of Potassium Permanganate 0,1 M.



Information:

A. Reactors capacity 2000 mL
B. Carbon graphite electrode size 0,5x1x10 cm
C. Magnetic stirrer
D. Pipe with diameters 2,5 cm and length 7 cm
E. Watermurr
F. Connection with negative electrode
G. Connection with positive electrode

Figure 2. Desaigning Microbial Fuel Cell.

The anode and cathode chambers connected with a salt bridge using PVC pipe (length= 7cm; diameter= 2,5 cm). This salt bridge membrane is made by dissolving 0,8 gr Lactose Broth and 1,5-2,0% Agar in 100 mL 3% KCl solution. And then stirring it until boiling on hotplate.

This MFC system uses a graphite electrodes with 10 cm long, 1 cm wide, and 0.5 cm thick. Before it used in the MFC system, graphite electrode is firstly immersed in the HCl solution for 24 hours, then in the NaOH solution for 24 hours, and washed for neutralization.

Prior to experiments on MFC reactors, the wastes were characterized in advance to determine the value of Optical Density (OD), Total Dissolved Solid (TDS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), and pH.

The performance of electricity producing of Dual Chamber Microbial Fuel Cells (MFCs) using wastewater of tempe industries without glucose addition (as control substrate) and with (2% and 4%) glucose addition was observed during 72 hours.

RESULTS AND DISCUSSION

Anode and Cathodes Reaction

The wastewater of tempe industry used in the MFC system is an organic waste in which there are many proteins, fats, and carbohydrates. The waste is also overgrown with many microorganisms because organic compounds are the easiest medium for microorganisms to grow. Organic compounds contained in this waste serve as a food source to perform metabolic processes by these microbes. Through this metabolic process produced protons of H^+, electrons, and CO_2. The produced proton diffuses through the salt bridge to the electrolyte solution present in the cathode chamber, while the electrons will be carried by a riboflavin mediator naturally owned by the bacterium to the electrode in the anode chamber which then flows into the electrical circuit of the established MFC system. The flow of electrons from the anode to the cathode generates electricity. At the cathode electrons, protons, and oxygen combine to form H_2O. In general, simple sugars as biodegradable molecules are degraded as indicated in the reaction (You et al., 2006) as follows.

$$\text{Anode: } C_xH_yO_z + H_2O \xrightarrow{\text{microbes}} CO_2 + e^- + H^+$$

The electrons are captured by permanganate in the cathode space and react with H + to produce H_2O, the reaction formed can be written as follows.

$$\text{Cathode: } MnO^{4-} + 4H^+ + 3e^- \longrightarrow MnO_2 + 2H_2O$$

Optical Density (OD)

The absorbance measurements were performed during the running of the MFCs system reactor. Spectrophotometer can be used to measure the turbidity of an object through the value of Optical Density (OD). This method is often used to estimate the amount or mass of cells, one of which is microbial cells in solution (Novitasari, 2011). Optical Density (OD) derived from absorbance measurements of this experiment is shown in Figure 3.

Figure 3 shows a significant increase in absorption in the first 12 hours. It may be due to the lag and exponential phase occurred in the first 12 hours. In the exponential phase bacteria actively produce electrons through metabolic processes by utilizing available nutrients. Furthermore, the bacteria showed stationary phase up to 72 hours without showing any mortality phase. Apparently, the food reserves on the substrate are still a lot for the survival of existing bacteria.

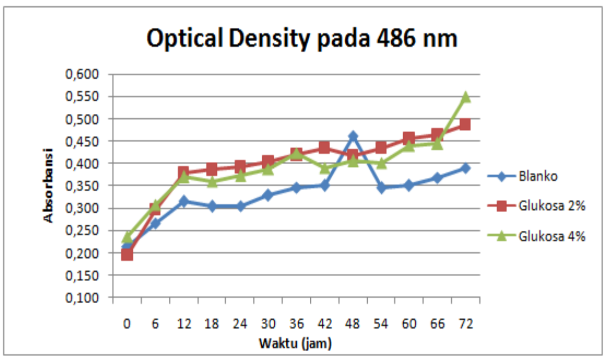


Figure 3. Result of optical density during the operation 72 hours on variation of Glucose Concentration.

Figure 3 shows that the optical density of the reactor with 2% and 4% glucose addition are higher than the control reactor (without glucose addition) almost all the time from the beginning to the end of the experiment. This suggests that glucose affects the rate of bacterial proliferation, resulting in higher absorption than control solutions.

Power Density

The value of power density in this experiment (Figure 4) represent the production of electricity generated by MFCs system. Figure 4 shows that the power density of control reactor is slightly higher than the reactor with 2% and 4% glucose addition, especially from 18 - 72 hours running time. This result is the opposite of the OD value indicated by the control reactor, where the OD value of control reactor is precisely below the OD value of the reactor with the glucose addition. It seems like that the OD value is not the significant factor affecting the value of power density.

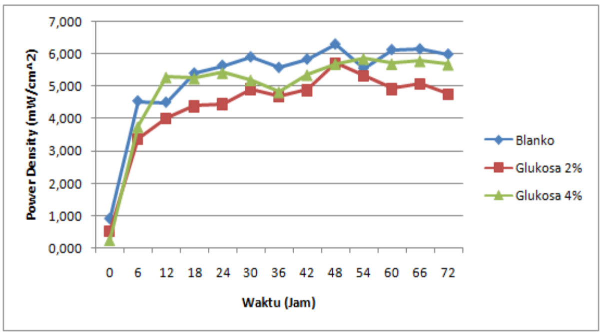


Figure 4. Result of power density during the operation 72 hours on variation of Glucose Concentration.

According to figure 4, pure industrial liquid tempe waste (control reactor) has produced the average of power density higher than the reactor with the addition of glucose. Glucose is a substrate that is widely used in MFC experiments to improve the production of electricity because it is easily oxidized by microbes (Kim et al., 1999). Unfortunately, in this study, the addition of glucose to the tempe wastewater industry is not significantly improve the electricity production in MFC system. Acetate is suggested as another nutrient that may be used to increase the production of electricity in the MFC system with tempe industrial liquid waste substrate (Chae, 2009 in Esther, 2012).

Chemical Oxygen Demand (COD)

In this study, the percentage of COD removal was about 1.52%, 9.76% and 9.64% of the control substrate, 2% and 4% glucose addition, respectively.

The rate of COD removal is quite high although not considered optimal yet. There is also a slightly increasing in COD value at 48 hours and then decrease at 72 hours in all variations. This relates to the electrical potential generated at 48 hours to the point where the power density value exists at the highest value obtained on the operation for 72 hours. According to Jenie and Rahayu (1993), the increase in COD value is also due to the increase of microbial biomass, so the amount of COD calculated is include the result of decomposition of cell biomass that is formed.

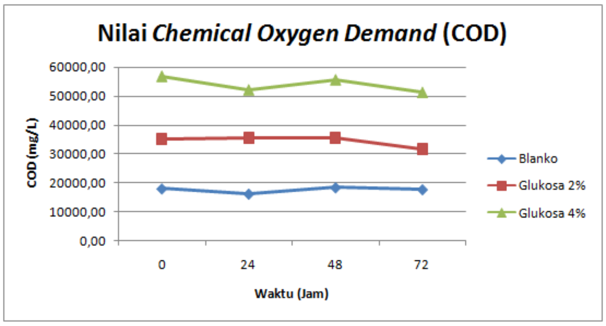


Figure 5. Chemical Oxygen Demand (COD) during the 72 Hours operation time.

Table 1. Result of liquid wastewater content analysis before and after running MFC.

Parameter	0 Hour	72 Hours	Unit
TDS (*Total Dissolve Solid*)	3.810	447	mg/L
COD (*Chemical Oxygen Demand*)	18.078,72	17.804,80*	mg/L
BOD$_5$ (*Biochemical Oxygen Demand*)	11.382,63	13.616,53*	mg/L
pH	7.77	8.85	-

CONCLUSIONS

Tempe industrial liquid waste can be used as a substrate on microbial fuel cell (MFC) reactor because in this waste there are many organic compounds that can be used as a source of microbial nutrients in the MFC system.

The results of Optical Density curves showed an increasing trend of absorbance during 72 hours of running time. These were in agreement with the resulting power density, which tended to increase until the 48th hour and then relatively stable especially for the substrate with 4% glucose addition. These MFCs system could also reduce COD by 1.52%, 9.76%, and 9.64% on control substrate, 2% glucose addition substrate, and 4% glucose addition substrate, respectively.

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