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Electric Potential Value of Microbial Fuel Cell Technology from Chinese Food Restaurant Waste Using Variation of Electrode Pairs

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Abstract

Indonesia's rapid population growth means that power demand will continue to rise year after year. Indonesia's growing population has resulted in an increase in restaurants, including Chinese food restaurants. As the number of restaurants grows, so does the amount of waste produce. Microbial Fuel Cells (MFC) that create electrical energy are one solution to this challenge. The study aimed to explore the utilization of MFC systems for power generation. It measured the performance of MFC in liquid waste in generating electrical value by utilizing a series of electrode types, particularly Aluminium (Al), Copper (Cu), Zinc (Zn), and Lead (Pb), and a blend of the four types of electrodes. The measured electrical value indicated that MFC can produce the high electrical voltage value was the pair of zinc (anode) and copper (cathode) of (0.863 V) and then the highest electric current value is 0.14 mA with electrode Cu and Zn. The maximum power density is 0.00464 W/m2 using a combination of Zn/Cu electrodes and then electrical energy with the highest value is 0.75168 J with Zn/Cu.

Keywords: Microbial Fuel Cell (MFC), Electricity, Chinese Food Restaurant Waste, Electrodes

INTRODUCTION

Electricity usage in Indonesia is rising year after year. Based on PLN Statistics in 2019, the overall output of PLN in 2019 was 270,975.97 GWh, an increase of 3,890.59 GWh or 1.46 % over the previous year. However, PLN has continued to use coal, a non-renewable energy source, as a fuel source for electricity production. The constant use of coal as a fuel source for generating electricity has been demonstrated to harmful environmental conditions such as global warming. This condition could certainly cause Indonesia to experience an energy crisis.

By utilizing waste, Chinese food restaurant waste has high enough pollutants. The treatment of Chinese food restaurant waste that would be unsuitable if left in the environment would reduce environmental quality. In addition, wastewater can carry waterborne diseases, microbes, infections, and foul odors that interfere with the health and beauty of the environment itself. Therefore, it is essential to control and supervise the wastewater of Chinese food restaurants with appropriate treatment.

One solution to the two problems mentioned above is to employ Chinese food restaurant waste in an MFC substrate capable of generating electric current. Zhang (in Novarina, 2018) argues that MFCs are bioelectrochemical that can convert chemical energy into electrical energy with the help of microorganisms. Microbes in MFCs may transform the chemical energy in the substrate into electrical energy, and microorganisms can transfer electrons from the metabolic product to the electrode. (Liu et al. 2004). MFCs can straightforwardly change over substance energy into electrical energy through bioelectrochemical responses using microorganisms or enzymatic catalysis (Das, Debabrata, 2018). The study of MFC is interesting because it can also overcome environmental problems and produce electrical energy. That could be an alternative solution to generating renewable electricity and support the realization that Indonesia will be energy independent in the future.

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LITERATURE REVIEW

Chinese food restaurant wastewater is liquid waste derived from restaurant waste. According to DLH Surabaya City (2019), Chinese food restaurant wastewater characteristics have a pH range of 6-8 with BOD and COD levels of 58-1,430 mg/L and 292-3,390 mg/L. It also has an oil and fat content of 120-712 mg/L and 13-246 mg/L suspended solids.

Microbial fuel cells (MFCs) are technical innovations that convert chemical energy into electrical energy via microorganisms' catalytic processes. MFC technology may be applied to liquid waste treatment, where the MFC system employs wastewater as a substrate to treat microorganisms appropriately. (Ibrahim et al., 2017). The natural matter present in theories squanders could be oxidized by these self- duplicating microscopic organisms otherwise called exoelectrogens through electron move responses to deliver the bioenergy. The microscopic organisms (known as exoelectrogens) are typically developed at the anode in an anaerobic environment to such an extent that they process the substrate (waste stream) and give the delivered electrons to the anode (which goes about as a terminal electron acceptor) (Sivasankar e al, 2018).

The process in microbial fuel cells (MFCs) uses bacterial digestion. Microorganisms metabolize glucose by converting it into hydrogen (H2) and oxygen (O2). Hydrogen is the raw material used in reduction reactions with oxygen, thus making electrons in the anode free as a source of electricity. MFC work systems may be utilized to generate energy from organic liquid waste. Some factors that can cause the creation of electrical value in MFCs to be less than ideal are the various constraints associated with the MFC such as reactor configuration, electrode and separator materials, anode and cathode catalysts, electron acceptor, substrate type, substrate concentration, feed pH, HRT and temperature that increase the internal resistance of the MFC. (Das, Debabrata, 2018). Some factors that can cause the creation of electrical value in MFCs to be less than ideal are the loss of activation and concentration (Moon et al., 2015).

The reaction to microbial fuel cells is as follows:

In the Anode Room :$(CH_2O)_n+H_2O \longrightarrow {}_nCO_2 + 4_nH^+ + 4_ne^-$ (Oxidation) (1)

In the Cathode Room : $O_2+4_nH^++4_ne^- \longrightarrow 2H_2O$ (Reduction) (2)

The overall reaction is the breakdown of the substrate to carbon dioxide and water with concomitant production of electricity as a byproduct. Based on the electrode reaction pair above, an MFC bioreactor can generate electricity from the electron flow originating in the anode and going to the cathode in the external circuit. Based on the transfer of produced electrons by active microorganisms from media to anode electrode, MFCs can be divided into two different types: firstly, MFCs with a mediator, where electron shuttles or mediators are added into the system; and secondly, mediator-less MFCs where no mediator needs to be added (Rahimnejad et al, 2015).

The various vital components in composing the MFC framework are chambers consisting of anode and cathode chambers, substrates, microbes, and membranes (Ibrahim et al., 2017). The electrodes are used as conductors that come into contact with the non-metallic part of the electrical circuit. The electric circuit is passed from one medium to the next, were first discovered by researcher Michael Faraday, whose name is taken from the Greek word electron. The study studied the use of MFCs as power plants. It measured the MFC's performance in generating electricity by utilizing various electrodes such as Aluminum (Al), Lead (Pb), Zinc (Zn), and Copper (Cu), as well as a combination of the four types of electrodes.

Table 1. The electrode material used in the experiment

Material	Atomic Number	Electron Configuration	Standard Electrode Potential
Copper	29	[Ar] $3d^{10}$ $4s^{1}$	0.34
Zinc	30	[Ar] $3d^{10}$ $4s^{2}$	-0.76
Aluminum	13	[Ne] $3s^{2}$ $3p^{1}$	-1.66
Lead	82	[Xe] $6s^{2}$ $4f^{14}$ $5d^{10}$ $6p^{2}$	-0.13

The University of Sheffield and Web Elements. Periodic Table.

There are numerous reasons why MFCs are more environmentally friendly when used in wastewater treatment. The capacity to directly transform substrate energy into electricity is the first advantage. Second, when compared to anaerobic digestion and CAAS processes, MFCs allow wastewater operations to produce less activated sludge. The third benefit is that it is unaffected by the operational environment. The fourth benefit is that, due of the recycling and conversion, MFCs do not require any gas treatment. MFCs can save a lot more energy because they don't require any aeration energy. Finally, MFCs can be widely used in areas where there is a lack of electrical infrastructure (He, L. et al, 2017).

RESEARCH METHOD

Tools and Materials

The MFC system used was a dual-chamber MFC reactor made of glass, consisting of anode and cathode chambers separated by a salt bridge. Other circuits were the Digital Multimeter, Zn Electrode, Cu Electrode, Pb Electrode, Al Electrode, Cover/Bulkhead, Cable, U Pipe Glass, Beker Glass, Measuring Glass, Filter, and Digital Scales. The sample materials used were the waste of restaurants or restaurants serving Chinese food, KCl powder, gelatine powder and aquadest.

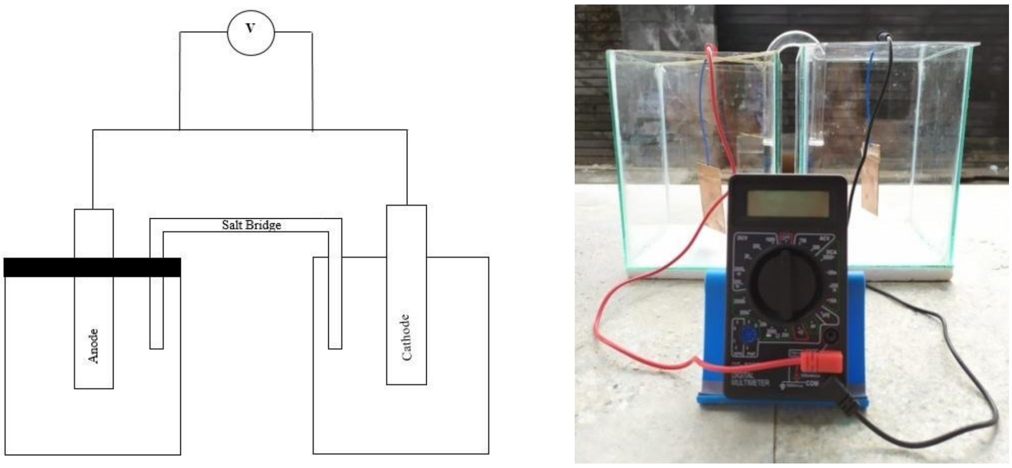
Procedure

1. **Wastewater Preparation**

   Chinese food restaurant wastewater samples that have been obtained and then put into a clean jerry can. Then the sample was mixed into one large container and then stirred. Finally, the sample in a large container was filtered using a filter equipped with filter paper.

2. **MFC Tool Assembly**

   The dual-chamber MFC system was assembled concerning by Novarina (2018) that connecting the two chambers with a salt bridge (a U pipe filled with gelatine mixture with 0.1 mol KCL powder).



(a) (b)

Figure 1. *(a) MFC tool design, (b) Microbial Fuel Cell (MFC) tool in research*

3. MFC running process

Researchers tested the electrodes Al, Cu, Zn, Pb as anodes and cathodes in each chamber in early experiments. By inserting liquid waste into the anode chamber and, at the same time, aqua dest was inserted into the cathode chamber and then conducting an electrical test for approximately 2 hours and measuring every 10 minutes. The following treatment replaced the pair of electrodes used by combining various variations of electrode type pairs.

Calculation of Power and Energy Density

The electrical value obtained in the experiment was voltage, and a strong current was measured using digital multimeters. The data were taken every 10 minutes for 80 hours. Researchers did calculations to get the value of power, power density, and electrical energy based on the data obtained. The following equations are used:

$$P = I x V \quad (3)$$

$$P_d = \frac{P}{A} \quad (4)$$

$$E = P x t \quad (5)$$

Description:

P = Power (W)
Pd = Power Density (W/m2)
E = Energy (J)
I = Current (A)
V = Voltage (V)
A = Anode Surface Area (m2)
T = Process Time (seconds)

FINDING AND DISCUSSION

Based on the research that has been done, performed of the electrical value of MFC includes electrical voltage, electric current value, power density value, and electrical energy results.

1. Electrical Voltage Value

Experiments were conducted on the MFC system. The voltage measured by a digital multimeter was connected to two electrodes on the MFC. The multimeter's negative pole was connected to the anode and the positive pole to the cathode. In this experiment, voltage measurements were completed without resistance or "external electrical loads such as resistors" so that the voltage measured on a digital multimeter was referred to as Open Circuit Voltage. The result of electricity in the form of voltage values is obtained as follows.

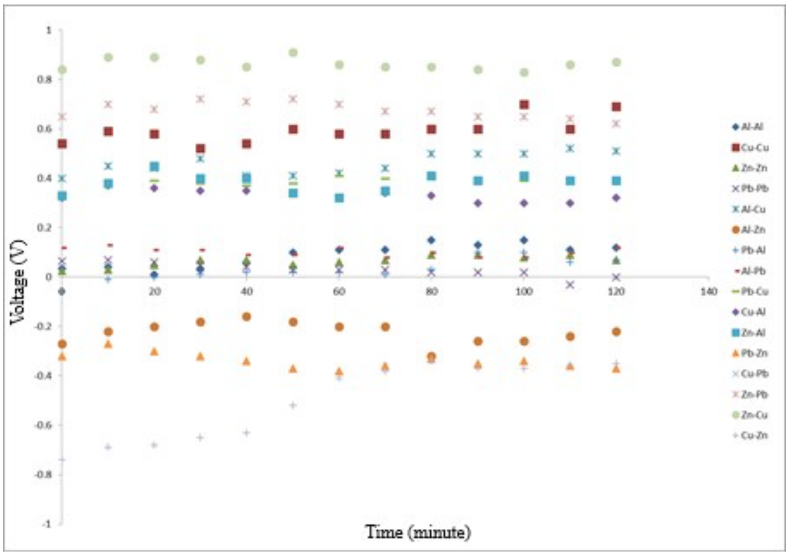


Figure 2. Graph of MFC system voltage results on different types of electrode combinations

The results showed fluctuating values for different types of electrode combinations. The increase or decrease in the value of the electrical voltage generated in MFCs has to do with the number of free electrons produced by bacteria in wastewater. The highest voltage value was 0.91 V, which occurred due to a sharp increase in microbial metabolism in decomposing organic substances indicated by an increase in the value of electrical voltage resulting from bacterial metabolism occurring. Then, the lowest voltage value time of -0.74 V. This results in a decrease in voltage due to reduced nutrients in the substrate due to microbial metabolic activity for several days. The number of electrons and protons to be sent will be reduced by decreasing nutrients, lowering the voltage value. (Ibrahim et al., 2017).

Likewise, Logan (2008) states that electricity production will be reduced if no organic material is left to oxidize. The electrical voltage value shows that the ideal treatment to produce the most significant voltage is a Zn electrode and Cu electrode with an average voltage value of 0.863 V. During the change of natural materials by the metabolic action of microorganisms, the created electrons are moved from anode to cathode compartment through the wire (Das, Debabrata, 2018).

2. Electric Current Value

Strong electrical current indicates the measure of the electric charge flowing in a delivery medium for each unit of time. Deliberate currents are generated because the ions present in the system move. Then, the differences in redox potential between the anode and cathode and the compound responses in the anode and cathode compartments. Strong current results were obtained as follows.

The strong value of current increased and decreased. In the end, it increased along with the length of the chamber. The experiment results showed that at the 0th hour, the activity of microorganisms did not play a role. The result of the highest electric current value is obtained after the process runs for 100 minutes in 0.14 mA in the combination of electrode Cu-Zn. It indicates that the movement of microorganisms plays a role in the decomposition of organic vows in wastewater. The longer the stay, the longer the contact time of microorganisms with wastewater and degrading organic substances, the more maximal.

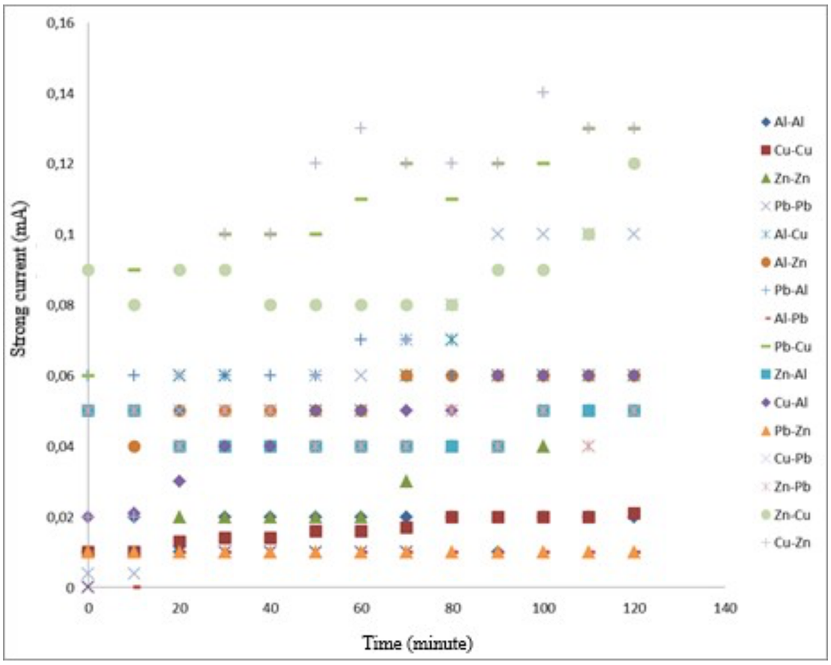


Figure 3. Graph of Strong Results MFC system current on different types of electrode combinations

During a certain time, the Electric Current Value in each combination of electrodes drops but is not very significant. Obstacles can cause this during the process. It can happen due to the absence of carbon sources used by microorganisms to produce electrons (Ali and Widodo, 2019).
Power Density Value
This power density was obtained from calculations by measuring the strong flow of current and electrical voltage data multiplied and then divided by the surface area of each electrode. In this study, the best electrode variation that produced the highest power density was the pair of Zinc in anodes and Copper in cathodes with a value of 0.00464 W/m2. The value of the power density is directly proportional to the value of the power generated. The surface area of the electrode used is 0.0225 m2. The increase in power density was not too significant in this experiment because the longer the processing time, the more biofilms could enlarge obstacles. If the outside of the electrode is filled with biofilms, the number of electrons that the electrode can move will be slight so that there will be a decrease in electrical value.

Electrical Energy Results
Based on the results of research, it showed that the presence of a medium attached influences the results of electrical measurements. Through Gibbs' free energy, microorganisms release energy during metabolism and development, where the value of this energy is controlled by the magnitude of electrical power each time. The dual-chamber MFC system in this experiment showed that, after some time, the energy generated in the system gets higher. During the 120 minutes of process, the greatest energy produced by microbes on the first measurement was 0.75168 J in the combination of electrode Zn-Cu. The amount of energy obtained in the system was also affected by the cell development of microorganisms. Enhancement of Parameters for the Increased Electricity Production by the Microbial Fuel Cell Using Substrates is the wellspring of the microorganisms during the bioelectricity age. Microscopic organisms develop by catalyzing compound responses and tackling and putting away energy as adenosine triphosphate (ATP). Park and Zeikus (2000) suggest that the number of electrons from a bacterial living cell is essentially greater than that produced by a bacterial cell at the time of development.

CONCLUSION AND FURTHER RESEARCH

The results showed that the resulting voltage value showed the pair of two electrodes that produced the highest voltage value in the experiment was the pair of zinc (anode) and copper (cathode) of (0.863 V) and then the highest electric current value is 0.14 mA with electrode Cu and Zn. The maximum power density generated from an MFC system reaches 0.00464 W/m2 using a combination of Zn/Cu electrodes. As well as using a combination of electrode types, Al, Cu, Zn, and Pb can convert organic compounds into electrical energy with the highest value is 0.75168 J in combination electrode Zn-Cu. But the value of electricity obtained during the experiment is still too small and cannot even turn on the lamp as an external obstacle. For advice, it is better to conduct further research using various factors, such as time used, substrate type, electron release media, area of the electrode, type of microorganism, and distance between electrodes.

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