Bioelectric production from sediment of pond fishing and molasses using microbial fuel cell (MFC) technology-base with the influence of substrate concentration variety

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Abstract. Indonesia is currently faced the problem of the need for electrical energy. MFC is a technology that can be used to generate electricity by utilizing microbial activity. The aims of this study is to manage the molasses waste and sediment of fishery as a substrate in the MFC system. The research method was performed by preparing anode and cathode connected by a salt bridge forming the system of MFC Double Chamber. The result of bacteriology test using Total Plate Count (TPC) method showed that the number of bacterial colonies on the sediment substrate was $4.1 \times 10^6$ cfu/gr, while the molasses substrate was $7.1 \times 10^4$ cfu/gr. The measurement result of electricity showed that 25% sediment and 75% molasses substrate variation resulted in the highest average voltage and power density that are 0.372 V and 813.191 mW/m\textsuperscript{2}. The conclusion of this research is that the mixture of sediment with molasses substrate can increase the production of electricity produced by MFC system.

1. Introduction

Indonesia is currently facing a difficult problem concerning the lives of many needs of electricity. The growth of the population causes the increasing demand for electricity while the supply of electricity is decreasing [1].

A new finding according to [2] shows that in the year 2011, the total oil reserve in Indonesia is as big as 7.73 billion barrels which consisted of around 4.04-billion-barrel reserve (proven) and 3.69 billion potential barrel reserves. In 2012, the total oil reserve decreases to 7.41 billion barrels consisting of 3.74 billion barrels reserve and 3.6 billion potential barrels reserve. If this situation is continuing to be ignored and Indonesia use only its fossil fuel source for satisfying its energy needs, the energy crisis in Indonesia in a few years will be unavoidable.

The energy crisis has started the development of renewable alternative energy source to substitute the usage of fossil fuels which has been the main source of energy for the people. The usage of microbes to produce electricity becomes something that scientists have put their hard work and effort into in the last few years. The system used is of Microbial Fuel Cell (MFC) which changes the stored chemical energy in the form of organic mixture into electrical energy which went through a catalysed reaction by
microorganism has resulted in an electrical energy. Microbes can be used in the MFC system to produce electricity while completing the breakdown process from organic materials [3].

The use of molasses and fish pond sediments in the application of MFC technology has become the alternative solution for the waste disposal which commonly produces a negative effect especially for the environment.

The source of glucose can be collected from molasses and fish pond sediment which is often found in a large amount in the surrounding area. Thus, the attempt to save the environment and optimize organic compounds, molasses and fish pond sediment can be utilized as a substrate for the MFC system to produce environment-friendly electricity.

According to [4] states that in general, mechanism process of Microbial Fuel Cell (MFC) is the oxidation of substrate by microbes producing protons and electrons in the anode. Electron is transferred through external circuit while proton diffuses through the solution to the cathode. The potential difference between anode and cathode along with the flow of electron produces energy.

2. Methods

This research is conducted in three stages. The first stage is construction of Microbial Fuel Cell covering the construction of the salt bridge and the electrode preparation. The second stage is the preparation of anode and cathode compartment covering the construction of the anode and cathode compartment. The third stage is the voltage output testing and the calculation of the power density produced.

The salt bridge is made by using a jelly material, KCl, with water. The ratio of agar and KCl used is 1:5. The jelly-salt KCl mixture is heated up in a pan until homogenous mixture is produced, then the mixture is put into a cylindrical tube.

The preparation process of the electrode starts by setting up the electrode graphite. This electrode is used as the independent variable, by changing the surface area of the electrode used. This electrode functions as a circuit in which a direct contact with the anolyte and catholyte occurs which produces a flow of electron from the anode to the cathode. The said graphite is submerged in HCl 1N solution for 1 day, then it is rinsed with aquadest and then submerged in the NaOH solution 1N for 1 day. Afterwards, graphite is stored in aquadest solution until it is ready to be used as electrode.

The anode compartment is filled with substrates to be used, which is the pond sediment and molasses. The collection of pond fish sediment substrate is located in the milkfish pond of Desa Mangkang Wetan, Tugu, Semarang. The collection of sediment was performed at the bottom of the pond with the depth of ± 100 cm using the tool Eikmann Grab. The sediments which have been collected are then inserted into a plastic container while still be immersed in water. Then it is stored in a cool box to preserve the sample temperature while the molasses substrate is taken from a farm shop in Ungaran, Semarang. The collected substrates are then fermented for 7 days. Fermentation is performed using closed 1 liter glass bottles. The substrate concentration used are sterile sediment 100%, sediment 100%, molasses 100%, sediment: molasses = 75% : 25%, sediment : molasses = 50% : 50%, sediment : molasses = 25% : 75%. The mentioned substrates are added with yeast which functions as the initiator, along with continuous stirring of the agar into a homogenous mixture.

The making of cathode compartment is by using K₂HPO₄ and K₃Fe(CN)₆ with 0,2 M concentrate. Both of them work very well as electron acceptor.

The testing towards voltage and power density produced by each research variable is done as well. Voltage from MFC system can be known by multimeter which is formed in parallel with the circuit while produced power density can be found with this equation:

\[
\text{power density} = \frac{V \times I}{A}
\]

Where power density (mW/m²) is power density produced, V (volt) is voltage or potential difference, I (mA) is electric current, and A(m²) is the surface area used by growing microorganisms in graphite anode.
3. Results and discussion

3.1. Water quality and fishery ponds sediment characteristic
The milkfish ponds water quality in Mangkang Wetan village, Tugu district, Semarang on 10.00 AM has temperature range between 35 – 36 Celsius degree and pH around 6.0-6.2. The value of water quality parameter is still on SNI 7310:2009 [5] range. Therefore, it's still good for fish growth and life sustainability.

Fishery ponds sediment in Mangkang Wetan village as one of MFC substrate is mud. Mud physically is gray ash colored. Generally, indicate the content of organic material including plant residues and humus. The amount of organic matter on gray ash colored sediment is higher than the brown sediment [6].

According to [7] suggest that the organic material content in a close ecosystem is relatively lower than the open one, such as sea and river. This condition is assumed due to the accumulation of affected organic material only. Besides, sedimentation rate and degradation rate of organic matter are very small. The differences found in substrate characteristics and the amounts of organic matter are expected to have an impact on existing MFC performance [8].

3.2. Bacteriology test on substrate
Bacteriological test was performed using Total Plate Count (TPC) method. This method can be used to determine the number of bacterial colonies on the substrate. The result of bacterial colonies in the sediments is $4.1 \times 10^6$ cfu / gr, that means there are 41 bacterial colonies in 1: 100000 dilutions ($10^{-5}$). The number of bacterial colonies in molasses is $7.1 \times 10^4$ cfu/gr, which means there are 71 bacterial colonies in 1: 1000 dilution ($10^{-3}$). The bacteria present in the sediment are more than molasses, this is indicated by the amount of dilution of sediments are more than the molasses.

Sediments and molasses have important natural microorganisms for the MFC system. Several types of bacteria which found in pond sediments are halotolerant bacteria, heterotrophic, and phosphate, nitrate, and ammonia bacteria. These three types of bacteria were found in pond sediment substrate [9]. Heterotrophic bacteria have a good metabolic, either in aerobic or anaerobic environments to break down organic material into inorganic [10], such as amino bacteria, nitrification bacteria and denitrification bacteria [11]. Phosphate-breaking, nitrate and ammonia bacteria decompose feed residues to supply N and P in ponds and the role of decomposing bacteria is critical [12].

3.3. Measurement results of electricity in MFC
Electrical production in MFC is calculated by analyzing closed circuit data with a load of 220 ± 5% which is measured every day for 10 days using a digital multimeter. The result of electrical voltage measurement generated by MFC can be seen in Figure 1.

![Figure 1. The graph of electrical voltage measurement results on MFC system](image-url)
The value of the voltage fluctuates in each observation. The value is related to the performance of the MFC. The MFC performance might also be affected by substrate degradation, velocity of electron transfer by bacteria to the anodes, proton transfer in the solution [13], microorganism’s activity, and the used substrate (in this observation, fishing pond sediments and molasses) [8].

According to the observation results, variations of substrate concentration will also affect the value of the voltage generated. In the observation, substrates with autoclave sterilized sediments produced the lowest voltage value and kept on degrading. The reason is because the substrate contained the lowest number of microorganisms and organic compounds.

The usage of 100% sediment substrate concentration produced an average voltage value of 0.309 V, and in 100% molasses substrate the average value produced is 0.314 V. The value is lower than MFC which used substrate mixture between sediments and molasses. The usage of substrate in ratio sediment: molasses = 75% : 25% produced average voltage value of 0.326 V, sediment : molasses = 50% : 50% produced average 0.358 V, and sediment : molasses = 25% : 75% produced the highest average voltage value of 0.372 V.

According to the graph in Figure 1, we can see that every MFC has its highest value then the degradation one. The degradation at the end of electricity measurements of the MFC occurred because as days pass, the nutrients contained inside the substrates are used for the bacteria’s metabolism activity, so the nutrients are reduced [14].

3.4. Calculation results of power density in MFC

Power density is used to know density values produced by MFC per surface unit. The calculations of power density values are generated from Equation 1.

In this observation, the radius of the electrodes used is 0.0025 m, and the height is 0.047 m. The surface area of the electrode, calculated with the calculations of the curve side with caps \((2\pi r^2+2\pi rt)\) is \(0.00077 \text{ m}^2\). The graph of the power density calculations is displayed in Figure 2.

![Figure 2. The graph of power density calculations results in MFC system](image)

According to the graph, it is discovered that the power density values will be proportional compared to the voltage produced. The average value of density produced by MFC with substrate variations are as follows: sterilized sediments produced 62.932 mW/m², 100% sediments produced 562.205 mW/m², 100% molasses produced 578.854 mW/m², sediment: molasses = 75% : 25% produced 630.776 mW/m², sediment : molasses = 50% : 50% produced 753.406 mW/m², sediments : molasses = 25% : 75% produced 813.191 mW/m².
3.5. Influence of electrodes surface area differences to voltage

In this observation, variations are applied to the surface area of the electrodes being used. The surface area of the first electrode is 0.00077 m$^2$, meanwhile the surface area of the second electrode being used is 0.00027 m$^2$. Figure 3 displays calculation results of voltage in the first electrode, while Figure 4 displays calculation results in the second electrode.

From both graphs, it can be compared if the difference of electrode sectional area will influence the voltage produced by MFC. From Figure 3 it can be seen that the highest value of voltage produced is 0.411 V in day 4 with sediment substrates variety: molasses = 25%: 75%, and the lowest value of voltage produced is 0.061 V in day 10 with sterile sediment substrates. Meanwhile based on figure 4 shows that the highest voltage value is 0.405 V in day 3 with sediment substrates variety: molasses = 25%: 75%, and the lowest value of the voltage is 0.060 V in day 10 with sterile sediment substrates. The average voltage value produced in Figure 3 displays a higher value than Figure 4.

![Figure 3](image-url)

**Figure 3.** The graph of the measurement voltage results of first electrode

![Figure 4](image-url)

**Figure 4.** The graph of the measurement voltage results of second electrode

The findings are suitable with [15] which said that if one of the factors which may influence the electricity production in MFC is the electrode sectional area. The wider the sectional area which directly interacts with the substrate thus the bigger probability of free electrons produced by microbe metabolism process to flow through the close line. As a result, the electricity production produced by the MFC system will increase as well.
4. Conclusion
The results of this research indicate the conclusion that the sediment of pond fishing and the molasses can be used as substrate in MFC. The mix up of sediment and molasses substrate can increase the electricity production result. The concentration of sediment substrate: molasses = 25% : 75% produces the highest average value of voltage and power density. The wide of sectional area influences the outcome of electricity production.

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