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Bioelectricity from Dual Chamber Microbial Fuel Cell (MFC) using *Aspergillus niger* with Sugarcane Bagasse Substrate

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Abstract: Electricity consumption is increasing, causing fossil fuels to run out more quickly. Various efforts are needed to develop renewable energy, including generating electricity. One of the developments in renewable energy comes from biomass. There are various types of biomass developed, one of which is biomass of microorganisms which carry out metabolic activities by utilizing organic material to produce metabolites which include energy. Microbial fuel cell (MFC) is a technology that produces electrical energy with the help of microorganisms that degrade organic materials through catalytic reactions or bioelectrochemical mechanisms from microorganisms. In this research, bioelectricity produced from MFC was tested using Aspergillus Niger with sugarcane bagasse as a substrate. The voltage value obtained from observations carried out for 15 days obtained a voltage in the range of 1.3-4.2 mV.

Keywords: *Aspergillus niger*; Bagasse; MFC; Microorganism; Substrate

Introduction

Electricity is a critical need for daily life for households, offices, and industry. The more residents there are and the more offices and industries, the higher the electricity consumption. This is shown by electricity consumption in Indonesia which is increasing every year. Based on data from the Central Statistics Agency (BPS) from 2015 – 2020, electricity consumption per capita has increased yearly as shown in Figure 1(Badan Pusat Statistik, 2023b).

Electricity use in Indonesia comes from several types of power plants. The type of power plant most widely used in 2023 is the steam power plant, which is around 49.75% of the total installed capacity (Badan Pusat Statistik, 2023a). This type of steam power plant uses coal which is a fossil fuel. If fossil fuels are used continuously, they will run out quickly. Therefore, various efforts are needed to develop renewable energy, including to production of electricity.

One form of renewable energy development is renewable energy originating from biomass. The biomass developed can vary, one of which is the biomass of microorganisms. Microorganism biomass carries out metabolic activities by utilizing organic material to produce metabolites which include energy.

Fuel cells are an alternative that can be used to overcome increasing energy needs. Fuel cells can be used to convert fuel into electricity directly through electrochemical reactions (Sulistyo & Darjat, 2016). This system is environmentally friendly, because it does not cause environmental pollution, and can even be used to overcome environmental pollution by utilizing waste (Sulistiyawati et al., 2020). In a fuel cell, there is a basic unit consisting of an anode, cathode, fuel, and electrolyte. At the anode, an oxidation reaction occurs and at the cathode, a reduction reaction occurs.

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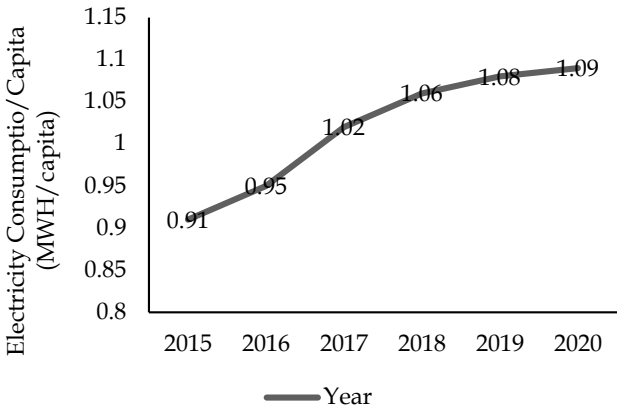

Figure 1. Per capita electricity consumption (MWH/capita) in Indonesia in 2015 – 2020(Badan Pusat Statistik, 2023b)

The technology currently being developed to produce bioelectricity is microbial fuel cells (MFC). Microbial fuel cells (MFC) have advantages compared to fuel cells, including the catalyst used is cheaper, the operating conditions are lower, the fuel used is cheaper and the fuel can be obtained from waste degradation. Microbial fuel cell (MFC) is a technology that produces electrical energy with the help of microorganisms that degrade organic materials through catalytic reactions or bioelectrochemical mechanisms from microorganisms (Kumar et al., 2019; Nyoman et al., 2011; Riscahya et al., 2021). Various types of microorganisms play a role in MFC, the use of microorganisms can be aerobic, facultative anaerobic, or obligate anaerobic (Deng et al., 2020; Riscahya et al., 2021). Carbon is very suitable as a place for bacterial growth is easy to connect with cables and has a relatively low price so carbon is very suitable for use as an anode material (Ieropoulos et al., 2017). Microorganisms that live in the anode medium convert the substrate into products and energy.

Sugarcane is one of the main commodities of one of the state-owned enterprises in Indonesia. Based on data from the Central Bureau of Statistics, sugar plantations in Indonesia in 2021 covered an area of 488,900 hectares and produced around 2.41 million tons of sugar cane (Direktorat Statistik Tanaman Pangan, 2021). Sugar cane contains around 30% bagasse, so it can be assumed that from 2.41 million tons of sugar cane bagasse produces around 723,000 tons. Sugarcane bagasse contains 45.96% cellulose, 20.37% hemicellulose, and 21.56% lignin (Sutikno et al., 2015). Cellulose and hemicellulose in sugarcane bagasse can be used as a substrate for several microorganisms, namely Aspergillus niger, penicillium echinulatum, Trichoderma reesei, Ganoderma lucidum (Ajala et al., 2021). The activity of these microorganisms can be utilized in the MFC system. MFC utilizes the capabilities of microorganisms by degrading organic materials into energy (Winda Intan Novalia, 2018).

Method

Sugarcane Bagasse Preparation

The bagasse used as a substrate in this research was taken from a pure sugar cane drink seller in Tanjung Barat, South Jakarta. The bagasse is then separated from the skin. The bagasse that has been separated from the skin is then oven to 80 ^{o}C for 30 minutes and then blanched until it becomes slightly smooth.

Manufacturing of MFC reactors

In this research, a double chamber-type MFC reactor was created. This reactor was made using acrylic material measuring 15 cm x 20 cm x 15 cm with a partition in the middle of the reactor. The membrane used in this MFC reactor is a proton exchange membrane Nafion 117 with a contact area of 16 m2. The electrodes in the reactor are connected using copper wire which is then connected to the Arduino reading system to show the resulting voltage.

Membrane Preparation

Before being installed in the reactor circuit, preparation of the membrane is carried out. The proton exchange membrane nafion 117 was boiled with 3% hydrogen peroxide (H_2O_2) for 1 hour at a temperature of 80 ^{o}C and then rinsed using distilled water. Next, the membrane was boiled using 1 M sulfuric acid (H2SO4) for 1.5 hours at a temperature of 80 ^{o}C then rinsed using distilled water. Before being installed in the reactor circuit, the membrane is dried by air.

Electrode Preparation

The electrode used in this research is copper (Cu). The electrodes are cleaned from dirt and biofilm attached to the electrodes. To clean dirt and biofilm attached to the electrode, sand the electrode until it is clean.

Microorganism Preparation

The microorganisms used are in the form of microbial isolates which will react with substrates containing cellulose and hemicellulose. The isolate used was Aspergillus niger which was obtained based on pure commercial laboratory cultures and isolates from private collections.

Isolates were prepared for culture according to the reference medium for each isolate. Biocatalyst preparation was carried out by making a basal growth medium in a test tube consisting of a mixture of 1 liter of distilled water, 70g peptone, 1g NaNO3, 1g KH2PO4; 0.5g MgSO4 and 30g olive oil, and media pH 6.5. Media and 80 polyurethane biomass support particles (BSPs) were sterilized by autoclave (121 ^{o}C for 15 min). Next, inoculate the microbial isolate from the petri dish. The

reaction tube was incubated at 25 °C on a reciprocal shaker (150 rpm) for 90-144 hours to immobilize the isolate then added 1.01-1.0 vol.% glutaraldehyde (GA) solution (for the last 1 hour). BSPs were then separated from the culture medium after incubation and water washed before freeze-drying.

Implementation of experiments

After substrate preparation and microorganism culture have been completed, the microbial inoculum is inoculated on the substrate. The substrate and inoculum in the bioreactor were incubated for 24 hours before observations. The experiment was carried out by observing the voltage (mV) and then measuring the voltage (mV).

Result and Discussion

The bioreactor used in this research is a dual-chamber microbial fuel cell consisting of chambers for the anode and cathode with a proton exchange membrane Nafion 117. The dual chamber MFC system is an MFC system that is often used (Salahudin & Hidayat, 2014). In this study, voltage measurements were carried out for 15 days, and measurements were taken every day.

The dual chamber Microbial Fuel Cell (MFC) consists of an anode and cathode. Fill the anode with bagasse mixed with water and add Aspergillus niger microorganisms and fill the cathode with water. At the anode, the fuel is oxidized by microorganisms, as part of the digestive process, the bacteria produce positive ions (H+) and electrons (e-). Electrons will be pulled out of the solution or transferred through the electrode to the anode (Nyoman et al., 2011). An external electrical circuit with resistance is needed to flow electrons that are connected to the electrode at the cathode. In the MFC, oxidation and reduction reactions occur. The reactions that occur are:
Reaction for electron donors (oxidation reaction at the anode):

$$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$$

Reaction for accepting electrons (reduction reaction at the cathode):

$$O^2 + 2H^+ + 2e^- \rightarrow 2H_2O$$ (Widodo & Ali, 2019)

The results of measuring the voltage values produced in this research are listed in Table 1.

Table 1. Results of voltage measurements for 15 days

No.	Time (Day)	Voltage (mV)
1.	0	0
2.	1	1.3
3.	2	1.8
4.	3	2.1
5.	4	2.5
6.	5	3.0
7.	6	3.3
8.	7	3.8
9.	8	4.2
10.	9	3.9
11.	10	3.5
12.	11	3.1
13.	12	2.8
14.	13	2.5
15.	14	1.9
16.	15	1.5

From the voltage measurement results as shown in Table 1, there were changes in electrical voltage that occurred over 15 days. There is Aspergillus niger activity in the MFC bioreactor which is indicated by an increase and decrease in voltage values. Aspergillus niger which lives on sugarcane bagasse in the anode medium converts the substrate into products and energy. When measuring at 0 days, no voltage was obtained. On the 1st day of measurements, a voltage of 1.3 mV was obtained. This shows that Aspergillus niger has adapted to the sugarcane bagasse subtraction after an incubation period of 24 hours. Furthermore, on days 2-8, the voltage measurement results continued to increase. This increase in voltage indicates that Aspergillus niger is entering the exponential phase. This means that Aspergillus Niger can carry out active metabolism accompanied by cell division so that the Aspergillus niger in the anode chamber increases in number. The more Aspergillus niger that undergoes metabolism, the more protons and electrons are produced so that the electricity production produced is greater. On days 9-15, there is a decrease in voltage. This is because the glucose concentration in the substrate decreases, causing the bacteria to no longer metabolize or die. Based on research conducted by (Christwardana et al., 2021), the use of a greater substrate concentration can produce higher voltage because it increases conductivity. Apart from that, a decrease in voltage can also occur because living and dead Aspergillus niger cells can form an increasing anode layer. If the electron surface is filled with biofilm, the number of electrons transferred to the electrode will decrease, resulting in a decrease in voltage (Du et al., 2007). The same statement was also conveyed by (Utami et al., 2018) from the results of the research carried out, that the voltage is directly proportional to the concentration of the substrate provided for oxidation. Apart from that, the

presence of metabolic enzymes can also influence the electrical voltage produced by MFC (Salahudin & Hidayat, 2014).

Several studies have been carried out regarding MFC using various kinds of substrates on the anode and cathode as shown in Table 2 below:

Table 2. MFC using various kinds of substrates on the anode and cathode

MFC Reactor Type	Anode	Katode	Power or voltage produced
Dual Chamber	Wastewater leachate	Leachate limbah	330 mV (Nguyen & Min, 2020)
Dual Chamber	Urban wastewater	BG 11	126 mW/m^3 (Bazdar et al., 2018)
Single Chamber	Kitchen liquid waste	Kitchen waste	6.150 mW/m^3 (Hou et al., 2016)
Dual Chamber	Activated sludge	BG 11	36.4 mW/m^2 (Zhang et al., 2018)
Dual Chamber	Food liquid waste encer	BG 11	32.5 ± 0.5 mW/m^2 (Naina Mohamed et al., 2020)
Dual Chamber	Food liquid waste	BG 11	41.5 ± 1.2 mW/m^2 (Naina Mohamed et al., 2020)
Dual Chamber	Kitchen liquid waste	Basal media	153 mW/m^2 (Kakarla & Min, 2014)
Dual Chamber	mixed anaerobic waste sludge in synthetic wastewater	BG 11	6,400 mW/m^3 (Jadhav et al., 2017)
Dual Chamber	Anaerobic sludge	Aerasi BG 11	19,151 mW/m^3 (Hou et al., 2016)
Dual Chamber	Citrus fruit waste	-	805 mV (Latif et al., 2020)
Single Chamber	Bagasse	-	0.154-0.313 V (Christwardana et al., 2021)
Dual Chamber	Bagasse	water	1.3-4.2 mV (this work)

Based on research that has been carried out to produce bioelectricity using MFC, the research currently being carried out is the one that produces the smallest amount of electricity. This can be caused by several things, including less rapid activity of microorganisms, very few microorganisms used, and lower substrate concentration. Substrates added with microorganisms will produce greater tension compared to pure substrates and substrates with added nutrients will produce greater tension compared to substrates without added nutrients (Latif et al., 2020).

Conclusion

Bioelectricity can be produced from MFC using aspergillus niger with sugarcane bagasse as a substrate. The highest voltage value was produced on day 8, namely 4.2 mV. The decrease in voltage values on days 9-15 can be caused by Aspergillus niger not metabolizing or dying due to lack of glucose.

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Author Contributions

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper

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