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Research Article

Potential of vegetable waste as alternative production bioelectricity

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ABSTRACT

Energy use is closely related to world economic growth and urbanization. Therefore, research was carried out by utilizing organic vegetable waste as a source of renewable energy. This study aims to determine variations in incubation time of vegetable waste that affect electricity production and to determine differences in bio-electricity production based on variations in incubation time of vegetable waste. The results of bioelectricity measurements in the Microbial Fuel Cell reactor, the maximum production of bioelectricity is found at the incubation period of 7 days, namely 9.48 mA at the 0th minute (initial), the maximum electric voltage is 288 mV at the 60th minute, the maximum power is 2205.50 mW in the 30th minute, and the maximum power density is 152.10 mW/m^2 in the 30th minute.

Keywords: renewable energy, vegetable waste, microbial, bioelectricity

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INTRODUCTION

Energy use is closely related to world economic growth and urbanization. It is estimated that 35% of energy will be consumed in 2035 compared to 2014, and 80% of the total energy demand will be supplied from fossil fuels (Wang & Yin, 2017). However, some environmental problems are caused due to, continuous dependence on fossil fuels, which in turn has a serious impact on sustainable human development. In addition, the limited reserves of fossil fuels make it difficult to meet the rapidly increasing demand. Therefore, handling the energy crisis and environmental degradation is very urgent and can eventually cause the depletion of fossil fuel reserves in the near future (Wang & Yin, 2019; Penniston & Kana, 2018; Putra et al, 2012). Another side effect of burning fossil fuels is for the environment, it results in the release of various pollutants including greenhouse gases, and hence raises concerns about global climate change (Liu et al, 2011; Van Ginkel et al, 2001). These challenges encourage us to look for alternative energy sources that are sustainable, renewable and non-polluting (Perera et al, 2010).

The exploitation of renewable and clean alternative energy is considered as a promising method. Renewable energies such as wind energy, solar energy, water generation, biomass, tidal energy and geothermal energy have been explored. Renewable energy is expected to increase by around 3% of the current total energy supply to 9% in the next 20 years. Renewable energy is the fastest growing energy source, accounting for about half of the energy increase. Natural gas is growing much faster than oil and coal. The abundance of energy supplies is playing an increasingly large role in shaping the global energy market (British Petroleum Outlook, 2018, 2017, 2016). Currently, the Indonesian government is paying more and more attention to the use of organic waste as a source of energy through the use of certain technologies. The waste generated by the community can be a source of energy that can be utilized and is estimated to be capable of producing a potential of around 2000 MW. It should be realized that organic waste has the potential for biomass energy which can be converted into other forms of energy, one of which is electricity. Electricity is a very important need in a country. In Indonesia, electricity consumption increases every year in line with increasing economic growth. Based on data from the Ministry of Energy and Mineral Resources, in 2017, Indonesia experienced an increase in electricity consumption of 1,012 kWh/capita, up 5.9% from the previous year (Latif et al, 2020).

As time goes by, the source of electrical energy derived from fossil fuels will decrease and can run out. Today the use of biodiesel as a source of electrical energy is using MFC (Microbial Fuel Cell). MFC produces electrical energy through a redox reaction from a hydrogen fuel. One way to produce hydrogen is by utilizing the fermentation process of organic substances by microbes (Gadkari et al, 2019; Santoro et al, 2017). This research will develop an MFC that can be made in a practical and low-cost manner because the source of nutrition for microbes can be obtained from market or domestic waste, namely vegetables, fruits, and animal meat scraps which are very easy to obtain even without costs compared to using pure glucose or maltose which are purchased at quite expensive prices (Latif et al, 2020).

Organic waste which originally caused environmental pollution can now be used as a source of nutrition for microbes which will then convert organic matter from the waste into electrical energy (bioelectric). The use of organic wastewater in the MFC system has several advantages, namely contaminants in wastewater can be a source of carbon (C) for MFC. The high carbon composition of organic waste is used by microbes to produce energy (Definiati et al, 2019). Therefore, organic waste is very well used as a source of nutrition in the MFC system. Utilization of organic waste in the MFC system is expected to be an alternative for organic waste treatment because, as the population increases, it causes an increase in the consumption of goods and services, there will be an increase in the volume of waste (waste) (Ruban et al, 2014) which can cause environmental pollution. So, organic waste needs to be managed properly and correctly, one of which is to use it as a renewable energy substrate.

METHODS

This type of research is descriptive quantitative, namely research where the data is obtained from a sample of the research population which is analyzed according to the statistical method used and then interpreted.

This research was conducted at the FKIP Laboratory Basic Biology, from 7-29 March 2022. The sample for this study was organic (vegetable) waste. Long incubation treatment of waste 7 days and 14 days. The results obtained were analyzed descriptively.

1. Tools and Materials

The tools and materials used for research on microbial fuel cell-based bio-electricity production, namely MFC reactors, digital multimeters, alligator cables and clamps, analytical scales, stirring rods, beaker glass, measuring cups, erlenmeyer, spatula, volume pipettes, dropping pipettes, carbon rods , cooper wire, cling wrap, aluminum foil, NaOH, HCl, distilled water, phosphate buffer, and vegetable waste.

2. Preparation of Electrolysis Equipment (Bioreactor)

The electrolyzer used in the MFC system is prepared before use. The electrolysis equipment used is equipped with microbes, salt bridge, carbon electrodes, copper wire, alligator cable, and multimeter.

a. Salt Bridge Preparation

Prepare 14.625 grams of NaCl with 250 mL of water and add a packet of agar powder and stir until well blended. After that, the solution was heated for 15 minutes until it boiled. If the solution has boiled, remove it, and leave it until the solution is warm. After that, put the solution into a glass tube, one end of which is closed so that the solution does not come out. If the solution has been put into a glass tube, leave it until the solution hardens. If the solution has hardened, the salt bridge is ready and ready to be used for research. Make sure that both ends of the salt bridge enter and attach to both compartments.

b. Electrode Preparation

First sand the surface of the electrode to remove any dirt and biofilm that has formed on the surface. The electrode used was carbon, the electrode was immersed in 1 MHCl solution for 1 day then rinsed using distilled water. After that the electrodes were immersed again in 1 MNaOH solution for 1 day then rinsed again using distilled water. The electrodes are immersed in an aquadest solution until they are used.

3. Substrate Preparation

The substrate that had to be prepared in this study was organic (vegetable) waste.

a. Waste Preparation

Vegetables are blended with 500 mL water for 15 minutes then filtered the water (Ibrahim et al, 2017; Kristin, 2012). Then stored in a jar and covered with aluminum foil and covered with cling wrap. Wastewater was incubated for 7 days and 14 days.

b. Variation of Substrate Incubation Time

In experiments with vegetable waste substrates, the anode compartment was filled with 200 mL of organic waste with an incubation time of 7 days and 14 days and the cathode compartment was filled with 200 mL of water. To each compartment 50 mL of 0.1 M phosphate buffer solution was added.

4. Measurement of Current Strength in the MFC System

a. Measurement of electric current and voltage using a digital multimeter.

b. Digital multimeter calibration before use to measure current strength.

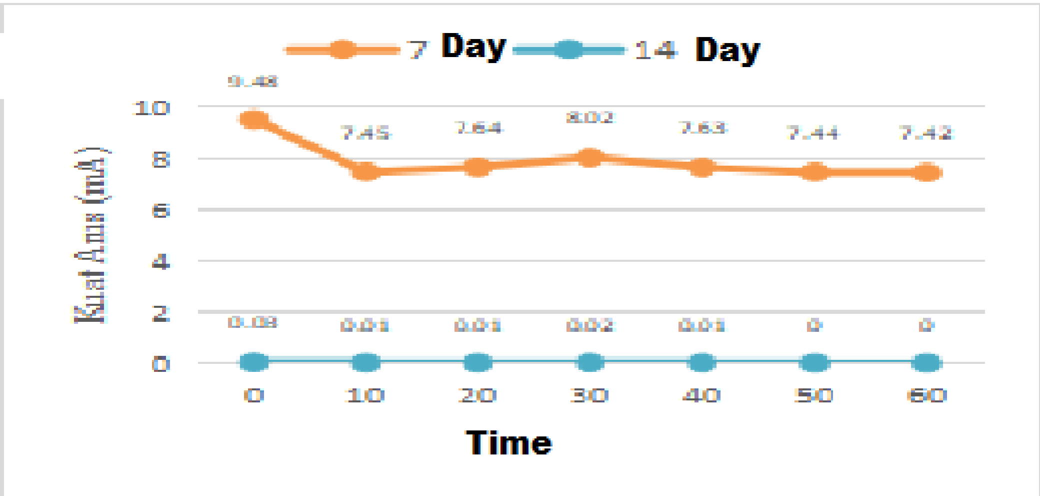
c. Electrical measurements are carried out every 10 minutes for 60 minutes (1 hour).

d. After that, the data obtained during the measurement of current strength is processed to obtain the value of power density (mW/cm^2) (power per unit area of the electrode surface).

RESULTS AND DISCUSSION

Uji Penggunaan Reaktor *Microbial Fuel Cell* terhadap Limbah Sayur

Measurements carried out in this study were measurements of bioelectricity production (electric current strength, electric voltage, power, and power density) produced by Microbial Fuel Cells (MFC) using organic vegetable waste. In this study, variations of storage time were used, namely 7 days and 14 days. The significance of the measurement results of bioelectricity production using the MFC reactor with variations in storage time is shown in the graph below.



Graph 1. Graph of measurement of electric current Strength

The graph above shows that the results of measuring electric current (I) in the two variations of storage duration have different values where vegetable organic waste with 7 days of storage has a significantly higher electric current strength than vegetable organic waste with 14 days of storage. Microbial Fuel Cells (MFC) in this study consisted of two separate chambers, namely the anode chamber and the cathode chamber. The two chambers each have graphite electrodes taken from the battery. Then the two chambers are separated by a salt bridge, with a long operating time of 60 minutes at room temperature. The vegetable waste used in this study was obtained from domestic waste which was collected for several days, namely 7 and 14 days. Vegetable waste is placed in an anode chamber which is anaerobic (tightly closed), this is done because if there is oxygen in the chamber it will hamper electricity production. The anode chamber in this MFC system is operated without the use of mediators or mediator-less, so the electrons produced by microbes through the process of degradation of organic compounds will directly go to the electrodes without the help of chemical additives (Akbar et al, 2017). The success of MFC performance is determined by the processes that occur in the anode and cathode chambers. The most influential process for producing electrical energy is the initial process that occurs in the anode chamber, namely the rate of substrate conversion by microbes and the rate of transfer of electrons from microbes to the surface of the electrode at the anode (Indriyani, 2017).

Microbes of vegetable waste in the anode chamber will stick to the anode electrode and then oxidize organic compounds in vegetable waste and produce protons, electrons and carbon dioxide as oxidation products (Utami et al, 2018). The microbial exploration used in the MFC system consists of 2 microbial groups, namely the electrifying microbial group and the fermentative microbial group. Fermentative microbes generally convert easily fermentable substrates such as glucose into short-chain organic acids, hydrogen (H) and carbon dioxide (CO2) (Lovley, 2006). The electricity production of the fermentative microbial group results from the interaction of reduced compounds resulting from the fermentation process under low redox conditions or from the few electrons generated by the fermentative microbes to the anode surface. However, the electrons that were initially in the substrate were mostly found in the electrochemically inactive fermentation products (inactive) (Lovley, 2006).

Bioelectrical measurements in this system do not use external electrical barriers or loads such as resistors, so that the measured voltage can be referred to as open circuit voltage. The average results of all observations show the best results in the MFC system with 7 days of storage. Increased bioelectricity production is possible because microbes are still in the lag or log growth phase which requires a lot of energy for growth, therefore the rate of substrate degradation/breakdown is relatively high so there is a possibility of a high level of electron production as well. Meanwhile, if the graph is flat or decreasing, it means the opposite is happening and it is possible that the stationary phase has entered, the microbial metabolism has slowed down or the microbes have entered the death phase (Indriyani, 2017). Degradation of organic material in vegetable waste produces electrons that can bind to the terminal electron acceptor (TEA) for example, oxygen, nitrate, nitrite, sulfate, etc. which diffuse through the cell, then these electrons are captured by the cathode which then generates a potential difference resulting in bioelectricity (Ibrahim et al, 2017; Fux & Siegrist, 2004). The increase and decrease in the production of electricity generated in the MFC reactor is influenced by electrons produced by microbes. The increase in electricity production can also be caused by the interaction and competition of microbes for the substrate in the MFC reactor. While the decrease in electricity production occurs because the nutrients in the substrate are reduced due to microbial metabolic processes over time (Ibrahim et al, 2017).

An important factor that greatly affects the production of bioelectricity is the electron transfer mechanism itself. There are 3 kinds of electron transfer mechanisms in the MFC system, namely (1) direct electron transfer from the microbial cell wall to the surface of the electrode in the anode chamber. It should be noted that not all microbes have a direct electron transfer mechanism to the electrodes, therefore there are other mechanisms. namely; (2) utilizing biomolecules as electron shuttles (mediators) to the anode; and (3) transferring electrons through nanowires grown by microbes. The most effective electron transfer mechanism is direct electron transfer compared to the other 2 types of transfer mechanisms, because the direct electron transfer mechanism saves cell energy (Indriyani, 2017). The size of the salt bridge also affects the power density, the amount of power density generated depends on how short the salt bridge is in the reactor. The power density of the MFC system value of power density is directly proportional to the magnitude of the strong value of electric current, voltage, and power. The electrode used is in the form of a graphite rod with a surface area of 14.5 cm^2 (1.45 x 10-3 m^2). Power density itself shows the performance of the anode in flowing electrons to the cathode. The maximum power density generated in this study for the 7-day storage time measurement reached 152.10 mW/m^2 at the 30th minute while for the 14-day storage time measurement it reached 0.167 mW/m^2 at the 0th minute (early before the calculation was carried out). In addition to the several things that have been explained, there are other things that cause a decrease in bioelectricity production in this study, namely, a leak in the reactor which causes space for oxygen to enter so that the process of transferring electrons from the anode to the cathode is disrupted.

CONCLUSION

The best bioelectricity production was in the variation of incubation time of vegetable waste 7 days compared to 14 days. This is because the longer vegetable waste is degraded by microbes, the less nutrients are needed for microbial metabolism and this causes a decrease in bioelectricity production.

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