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Utilization of Banana Stem Waste Extracts Assisted by Electrode of Cu/Mg as an Environmentally Friendly Electricity Producer

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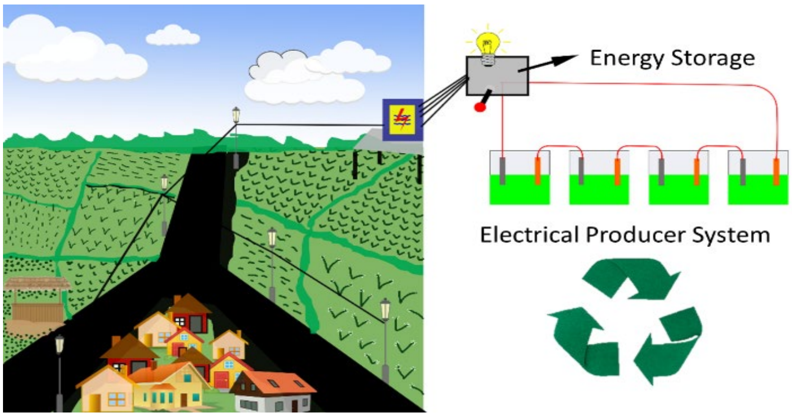
The high consumption of electricity from year to year and the depletion of the availability of fossil energy have triggered an increase in energy prices and scarcity of fossil resources. This problem gives a strong impetus to seek alternative energy sources that are environmentally friendly. One of the recent technologies is the Microbial Fuel Cell (MFC) on banana stem, which can convert chemical energy into electrical energy. The purpose of this study was to determine the potential of banana stem waste extract assisted by Cu/Mg electrodes as a source of electricity as well as how the manufacturing and testing methods, and the effect of variations in the volume of banana stem extracts on the performance of electrical energy. The used steps were electrode preparation and banana stem waste preparation, then incubating the banana stem waste for 7 days, assembling the construction for research on the potential of the banana stem waste as a power producer, and research with variations in the volume of the extract and testing its strength, electric current, electric voltage, and power density. Based on the research, it was found that the greater the volume of the extract of banana stem, the greater the power density, electric voltage, and also the strong electric current produced. The volume variation of 130 mL produced a voltage of 500 mVolt, a strong current of 0.86 mA, and a power density of 84 (mW/cm^2).

Graphical abstract



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1. Introduction

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The high consumption of electrical energy has caused problems in the 21st century. It is noted that the national electricity consumption was 910 kilowatt hours (kWh) per capita in 2015, and it increased to 1,084 kWh/capita in 2019 [1]. Fossil products such as oil, gas and coal have been exploited on a large scale, so that the availability of fossils is running low for the next few years. The impact of the need for electrical energy from fossils as a primary need is to trigger an increase in energy prices and the scarcity of fossil resources. In addition, the environment has been polluted due to harmful fossil exhaust gases. So, this problem has given a strong impetus to seek alternative, renewable and environmentally friendly energy sources. The development of alternative energy sources (renewable) has been carried out by many researchers to minimize the use of petroleum. One technology that has the potential to be used widely, economically, and environmentally friendly is the use of microbial fuel cells [2]. Microbial Fuel Cell (MFC) is an applied science of electrochemical cells based on certain microbes to convert chemical energy into electrical energy, these microbes degrade organic matter to produce electrons [3]. Many organic materials can be used as supplies in microbial fuel cells (MFC). However, these organic materials are needed in abundance, are easy to regenerate (grow back), and do not interfere with the availability of primary needs. In Indonesia, the potential organic material is banana stem.

Indonesia is a fairly large banana producer, 50% of Asian banana production is produced by Indonesia and its production continues to increase every year. Almost all parts of Indonesia are banana-producing areas. Rohmah explained that every year the land and banana production is increasing [4]. At harvest time, banana trees are taken from the fruit and banana leaves, then the stem are cut down and become waste. Facts in the community, banana stems are discarded and not reused. There is a use of banana stem waste so far it is still limited to handicrafts and arts.

Banana stems can be obtained from all types of bananas. The fast growth and development of banana plants, easy to regrow, and high organic matter (carbon) content has the potential to be used as an energy source. The organic material in question is cellulose. The presence of cellulose in the banana stem causes the presence of indigenous cellulolytic bacteria that can degrade the cellulose into simpler materials, so that the banana stem will rot and form a slurry. Through the process of slurry formation, electrons will be generated at the anode. The electrons at the anode are then flowed through an external circuit and react with electron acceptors at the cathode, so it is to produce electrical energy [5]. The use of waste in the MFC system has several advantages, such as contaminants in wastewater can be a source of MFC fuel to produce electrical energy while reducing the COD level of the waste [6]. Many studies using MFC by utilizing waste have been carried out, but there has been no research on MFC by utilizing banana stem waste with the help of catholyte Cu/Mg electrodes as a source of electrical energy. The use of Cu/Mg electrodes can increase electrical energy to be greater. Also, Cu/Mg electrodes have high potential energy that can support the electricity producer. Therefore, banana stem has the potential to be developed as an extract in microbial fuel cells (MFC) technology assisted by Cu/Mg electrodes, so the researcher offers an idea with the title "The Potential of Banana Leaf Extract Waste as a Cu/Mg Electrode Assisted Electricity Generator" that can reduce the banana stem waste that are underutilized and can produce electrical energy in a sustainable manner.

2. Results and Discussion

2.1 Potential of banana stem waste extract as a generating electrical energy assisted by Cu/Mg electrodes

Bananas have a high cellulose content. The rapid growth and development of banana plants makes the availability of banana stems very abundant. Banana stem waste contains high organic matter (carbon) which has the potential to be used as an energy source. The content of organic substances in banana stem can be degraded by the help of indigenous cellulolytic bacteria and combined with *Lactobacillus casei* bacteria. The degrading bacteria cause the banana stem to rot, resulting in the formation of a slurry. Through the process of forming a banana stem slurry with the help of bacteria, electrons will be produced which have the potential to produce electrical energy.

This slurry phase is used as a substrate in the anode compartment. Microorganisms that play a role in the MFC reactor get their food from the banana stem and from water which is used as a mixture of ingredients to form a banana stem slurry. Microorganisms attach to the anode under anaerobic conditions. Furthermore, there will be a process of degradation of the banana stem, so that carbon dioxide, protons, and electrons are obtained.

The degradation process of the banana stem includes an oxidation reaction. The process of forming electricity is from the process of converting cellulose compounds through the processes of hydrolysis, fermentation, and electrogenesis. Hydrolysis of cellulose is the process of breaking the bonds of b-1,4- glycosides in cellulose. The results of the decomposition of complex organic matter in the banana stem can be used as an energy source for bacteria for the next stage. Bacteria will grow when there are more sources of nutrients. The increasing rate of bacterial metabolism will increase the electric potential difference (voltage) produced. This is because the potential difference is equivalent to the concentration of electrons at the anode [8].

Proton transfer significantly affects the performance of the MFC. When the substrate in the form of rotten banana stem is degraded, protons are produced by the anode and consumed by the cathode. In biological systems, microorganisms use banana stem substrates to synthesize new cellular materials and provide energy for synthesis [9]. In the anode compartment, microorganisms will oxidize organic material under anaerobic conditions. This process plays a role in the production of electrons or electricity in the MFC reactor. With the presence of more microorganisms, of course, the oxidation process will run more and more. Electrons will flow through the anode compartment circuit. Next, the protons will pass through the salt bridge to stabilize the charge in both compartments. In this condition, there is a potential difference between the cathode and anode compartments. electric current [10].

2.2 Analysis of voltage and electric current test of banana leaf extract waste

It can be seen in the Fig. 1, the highest voltage value is in the volume of 130 mL banana stem waste extract of 500 mVolt. The larger the volume of the banana stem waste extract, the more organic matter content, besides the amount of oxygen contained in the 130 mL volume of the banana stem waste extract is less than the volume of 60 mL and 100 mL. This is considered quite appropriate because bacteria remodel organic substances under anaerobic conditions, meaning that these bacteria are able to metabolize better, if the oxygen content in the waste is low. Then, the results of the reshuffle in the form of electrons are channeled directly to the electrodes and produce electrical energy.

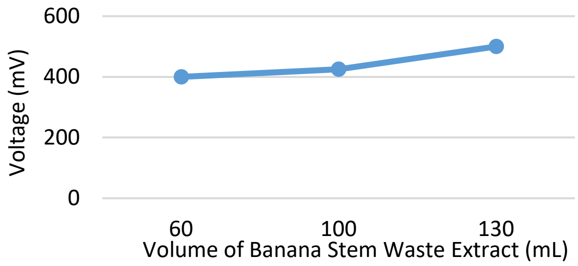

Fig. 1. Graph of electric voltage value.

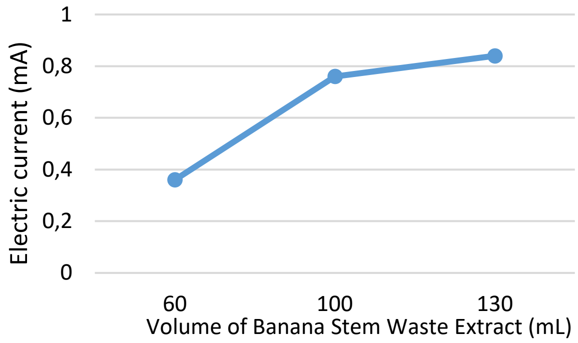

Fig. 2. Graph of electric current strong value.

From the results of the calculations in the graph of Fig. 2, it can be seen that the electric current generated from the volume variations of 60 mL, 100 mL, and 130 mL is 0.36 mA, 0.76 mA, and 0.84 mA, respectively.

2.3 Calculation results of power density (mW/cm^2) on the volume of banana leaf waste

As for how to calculate the Power Density on the volume of banana stem waste is as follows:

Power Density = (Voltage x Electric Current)/Area

Area = length x width, on the size of the Cu and Mg electrodes 5 cm x 1 cm, then,

(1) 60 mL,

Power Density= 400 mVolt x 0,36 mA / 5 cm^2

= 28,8 (mW/ cm^2)

(2) 100 mL,

Power Density = 420 mVolt x 0,76 mA / 5 cm^2

= 63,84 (mW/ cm^2)

(3) 130 mL,

Power Density = 500 mVolt x 0,84 mA / 5 cm2

= 84 (mW/ cm^2)

To compare the results of Power Density on the volume of banana stem waste at 60 mL, 100 mL, and 130 mL with an electrode size of 5 cm^2.

It can be seen in the graph of Fig. 3, the highest Power Density in the volume of banana stem waste is at 130 mL. It can be concluded that the greater the volume of banana stem waste with different electric currents and different voltages in each volume, the higher the power density.

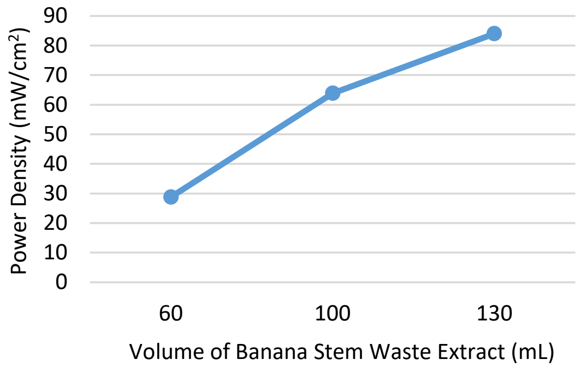

Fig. 3. Graph of power density value.

3. Material and Methods

3.1 Research design

The used method in this study was a laboratory experiment by: (1) extracting the banana stem, and adding aquadest, after that (2) the extract was incubated in a closed container for 7 days, and then (3) assembling a construction for testing the extract as a generator of electricity.

3.2 Material

The used materials consisted of rotten banana stem waste, Cu electrodes and Mg electrodes measuring 5 cm x 1 cm x 0.1 cm, aquades, lamps.

3.3 Instrumentation

Tools and other materials consisted of cup, knife, mortar, pestle, 500 mL beaker, plastic wrap, cable, LED light, multi-tester.

3.4 Procedure

Electrode preparation and banana leaf waste preparation

The electrodes must be prepared in the following steps. Copper (Cu) electrodes and Magnesium (Mg) electrodes were cut with a size of 5 cm x 1 cm x 0.5 cm. Then, the laye carefully cleaned using sandpaper. After obtaining the cleaned electrodes, they were stored in a closed place.

The banana stem waste was first mashed with a mortar and pestle, then it filtered and the essence was taken. Samples of banana stems that have been smooth were incubated by placing them in a container and tightly wrapped.

Incubation of banana leaf waste

The obtained banana stem waste extract was incubated in a tightly closed container, so that air could not enter. This process was carried out within seven days, so that the decomposition or degradation of the banana stem waste extract was more perfect to produce electrons due to the oxidation reaction.

Assembling a series of research construction

The series of buildings adapted to the research scheme. The circuit schematic can be seen in the Fig. 4.

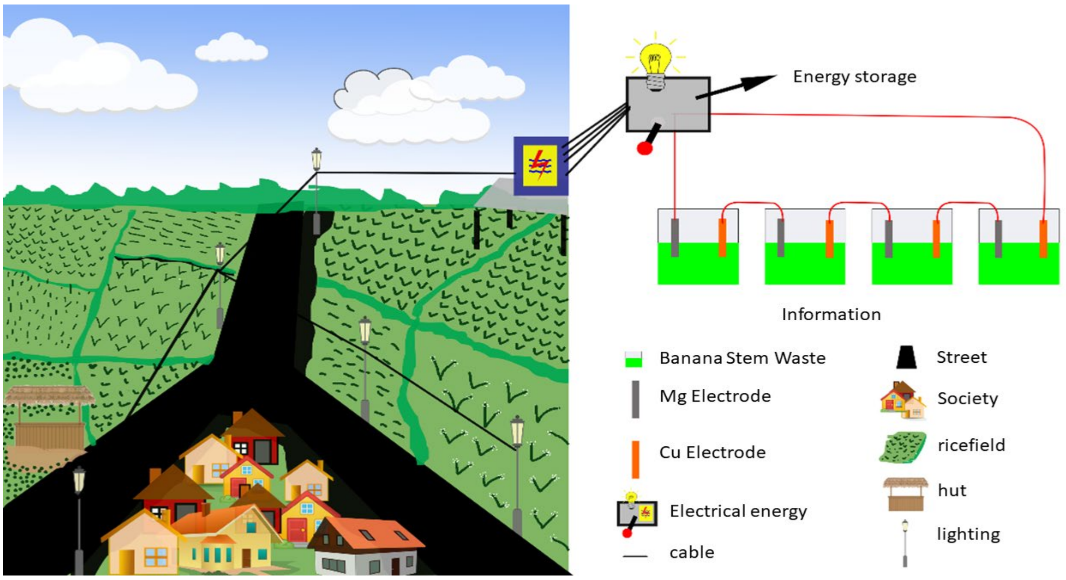

Fig. 4. Design the circuit illustration and implementation.

Experiment

This experiment or research was carried out according to a series of research constructions with variations in the volume of banana stem waste extract. The first variation with extract volumes of 60 mL, 100 mL, and 130 mL. The division of this variation aims to see the effectiveness given in generating electricity.

Test

To measure the amount of electrical energy produced by the MFC tool in this study, a multi-tester was used to measure the voltage and current. Before the measurement was carried out, the multi-tester is calibrated first. Data retrieval was taken according to time variations. The data in the form of current and voltage will be processed into the value of power density (mW/m^2), which is the power per unit surface area of the electrode. Power density can be calculated using the following equation [7].

$$\text{Power density } (mW/m^2) = I(mA) \times V(Volt)/A(m^2)$$

Analysis

The analytical method in this research was descriptive analytic, namely analyzing existing problems from observations or identification and literature studies about problems and the relationship between these problems based on a relevant scientific theory or concept.

4. Conclusions

Banana stem waste extract can generate electrical energy with the help of Mg and Cu electrodes. Banana stem waste extract can produce electrical energy because the banana stem is overhauled by microbes and produces a substance, namely electrons.

The manufacturing method of this research applies a simple electrochemical concept to the galvanic cell. Tests were carried out to measure the presence of electricity in the banana stem waste extract in the form of electrical voltage, current, and power density.

Volume variations in this study provide data at a volume of 13 mL resulting in the highest data at an electric voltage of 500 mVolt, a current of 0.84 mA, and a power density of 84 (mW/cm2).

Author Contributions

Deni Ainur Rokhim contributed with conceptualization, formal analysis, investigation, methodology and writing – original draft. Muhammad Roy Asrori & Endang Ciptawati contributed with investigation, visualization, writing – original draft and writing – review & editing. Firda Kristining Tyas & Ahmad Wahani Adid contributed with writing – review & editing.

References and Notes

[1] Kementerian Energi dan Sumber Daya Mineral. 2019. Rencana Umum Ketenagalistrikan Nasional Tahun 2019 Sampai Dengan Tahun 2038. Jakarta: JDIH ESDM. Available from: **https://jdih.esdm.go.id/storage/document/Kepmen-esdm-143-Thn%202019%20RUKN%202019.pdf**

[2] Riyanto, B.; Maddu, A.; Firmansyah, Y. 2012. *JPHPI.* **2012**, *15*, 183. **[Link]**

[3] Ibrahim, B.; Suptijah, P.; Rosmalawati, S. *JPHPI* **2014**, *17*, 71. **[Link]**

[4] Rohmah, Y. 2016. Outlook Komuditas Pisang. Edisi ke-1, Pusat data pertanian dan sistem informasi pertanian kementrian pertanian. Jakarta. **[Link]**

[5] Chae, K. J.; Choi, M.; Ajayi, F. F.; Park, W.; Chang, I. S.; Kim, I. S. *Journal Energy Fuel* **2008**, *22*, 169. **[Link]**

[6] Du, H.; Li, F.; Huang, K.; Li, W.; Feng, C. *Environ. Prot. Eng.* **2017**, *43*, 5. **[Link]**

[7] Momoh, Y.; Naeyor, B. *J. Biochem. Tech.* **2010**, *2*, 216. **[Link]**

[8] Marcus, A. K; Rittmann, B. News Archive of the Biodesign Institute. 2008. Available from: **https://biodesign.asu.edu/news/new-insights-fuel-cell-uses-bacteria-generate-electricity-waste**

[9] Logan, B. E. *Microbial Fuel Cell*. Hoboken: John Wiley & Sons, 2008.

[10] Imaduddin, M.; Hermawan; Hadiyanto. *Media Elektrika* **2014**, *7*, 22. [Link]

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