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Preface: The 3rd International Conference on Physical Instrumentation and Advanced Materials (ICPIAM) 2021

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Preface: The 3rd International Conference on Physical Instrumentation and Advanced Materials (ICPIAM) 2021

Physics Department – University of Jember, Indonesia, 27 October 2021

The 3rd International Conference on Physical Instrumentation and Advanced Materials (ICPIAM) 2021 is a serial international seminar held as a form of collaboration bi-annual event between the Faculty of Mathematics and Natural Sciences, University of Jember and the Faculty of Science and Technology (FST) Universitas Airlangga (UNAIR).

This conference (ICPIAM 2021) was held as a means for academics, scientists and researchers to discuss, share and exchange information, experiences, methods and research findings as well as the latest innovations at the international level. Through this conference, links will also be formed between researchers and academics to establish cooperation and collaboration both in the fields of education and research internationally.

This conference was attended by 60 presenters who have submitted paper from their studies and researches. They come from Japan, Malaysia, and mostly from Indonesia such as (BPPT, LAPAN, UNAIR, UNEJ, ITB, UNAND, UNCEN, and many more). All the presenters will convey their speech in the 6 different parallel rooms as given in the book of abstract. All presented and reviewed paper will be considered to be published at the AIP Conference Proceedings (Scopus indexed proceedings). We deeply thank the authors for their enthusiastic and high-grade contribution.

The 3rd ICPIAM 2021 would not be possible running without the dedicated efforts of many people especially all organizing committee members who have made planning and organizing the programs. We are grateful to IsDB and Jember University for the funding support, also Physics Student Association (HIMAFI) and volunteers who contributed to the various processes that make up the conference and it would not be possible for me to name them all in this short message.

Bowo Eko Cahyono, Ph.D.
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The impact of adding vegetable waste on the functioning of microbial fuel cell

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Tri Mulyono, Misto, Bowo Eko Cahyono, et al.

The Impact of Adding Vegetable Waste on The Functioning of Microbial Fuel Cell

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Abstract. As the demand for energy and power grows, so does the supply of fossil fuels, causing CO2 levels in the atmosphere to rise. The development of microbial activity-based fuel technology, also known as Microbial Fuel Cell (MFC), is an energy source that can be produced. The technology is one of the alternative technology systems as an energy supplier with fuel cells that can convert chemical energy into electrical energy through a microorganism catalyst process. This research will be disclosed about the effect of several types of main vegetable waste on the MFC power density. This MCF system is made from a plastic container that is given a soil medium that functions as a source of microbes and membranes and is equipped with graphite fiber electrodes. Organic materials that function as natural substrates for MFCs come from mustard greens, kale, and spinach. The MFC experiment was divided into two groups: (1) the group without the addition of vegetable waste, (2) the group with the addition of vegetable waste. The optimum power, 134 W, was produced by MFC on giving spinach dregs. The optimum power density value is 211 mW/m2, the optimum average voltage is 0.804 V, and the optimum current is 2.37 mA.

Keywords: *Microbial Fuel Cell*, Organic Waste, Power Meeting, Voltage, Current

INTRODUCTION

Microbial Fuel Cell (MFC) or microbe-based electrochemical cell, is one of the alternative technology systems as an energy supplier with fuel cells that can convert chemical energy into electrical energy through a microorganism-catalyzed process. The vegetable waste contains organic material that can be used as a nutrient for microorganisms in the MFC system. Nutrients are substances that organisms need to live and reproduce [1]. The MFC consists of an anode containing a microbial culture and an acidic potassium phosphate buffer (pH 7), a cathode containing an electrolyte KMnO4, and a potassium phosphate buffer at pH 7, a proton exchange membrane (PEM), and an external circuit. The substrate used in this system is activated mud soil which is used as a place for the growth of microorganisms [2]. The working principle of MFC is to utilize organic waste used by microbes as an energy source to carry out metabolic processes. The energy does not produce emissions CO2 that are environmentally friendly. Microbes metabolize without the use of oxygen (anaerobes). An electric current is generated when bacteria release electrons from the potential difference generated by the two electrodes [3].

Vegetable waste is part of vegetables that humans can no longer consume and we often find it in the market. Traders usually disposed of vegetable waste because it has no economic value. Vegetables that

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have a high water content make them easy to rot and cannot be stored for a long time. The amount of vegetable waste can pollute the environment because of the lack of utilization of the waste. The average daily number of averaged garbage reaches 8700 m^3 and is dominated by organic waste bins of vegetables and fruits by 87% [4]. The proper use of vegetable waste can reduce environmental pollution. Vegetable waste contains glucose which can be used for the consumption of microorganisms [5]. The utilization of waste used for MFC research has been widely carried out, including organic waste from livestock manure [6], food waste [7], and also fruit and vegetable waste [8].

This study aims to determine the effect of adding nutrient substrates from vegetable waste into soil media on the performance of single-chamber MFCs as well. They also studied the optimum performance of MFCs arranged in series and the effect of incubation time on the pH value. This research is expected to assist efforts to overcome vegetable waste by utilizing it as a substrate for MFC as an environmentally friendly producer of bioelectric energy for electrical energy.

RESEARCH METHODS

This research activity uses twelve MFC chambers, namely nine MFC chambers that are given vegetable waste, while the other three chambers (MFC-Kt) do not add vegetable waste. The nine chambers were divided into three groups where each group was given mustard greens (MFC-S), kale (MFC-K), and spinach (MFC-B) from each of the three chambers. These two types of treatment are useful for knowing the difference in power on all MFCs.

2.1 Design of *Single Chamber Microbial Fuel Cell*

The apparatus used consisted of a vessel with a volume of 500 mL equipped with a cover, two graphite fiber electrodes, and a soil medium (Figure 1). The anode and cathode are made of graphite fiber with an anode thickness of 0.5 cm; diameter of 8 cm which is connected to a green titanium wire, while the cathode has a thickness of 1 cm; diameter of 8.5 cm and is connected with titanium wire *orange* [9].

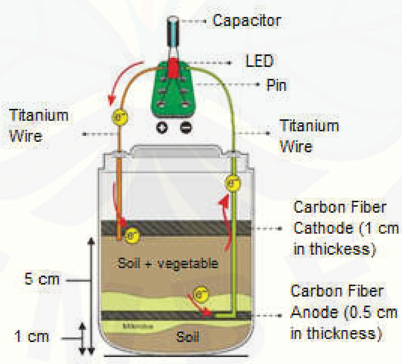

Figure 1. Design of MFC *single chamber*

The vegetable waste utilized has been placed in a closed container for three days so that the container space becomes tight and damp, allowing the decay process to proceed fast.. Vegetable waste was crushed using a blender so that vegetable juice with a concentration of 345 ppm was obtained. Measurement of this solids content using a TDS meter. Furthermore, this juice was added to the MFC soil media as much as 5 mL using an injection. The addition of vegetable waste is done every 10 days.

2.2 The measurement of MFC electric power

The measurement is carried out using the application *MudWatt* installed on the *cellphone*, the Oppo 2018. How to measure power by pressing the button *measure* on the application, then scanning the LED flame right in the middle. After the appears, the *Measuring Power message* waits for the power results to appear on the screen, then *records the* results so that they are saved. The resulting data will be stored in excel form.

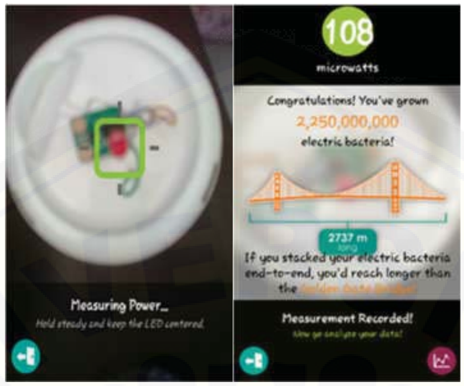

Figure 2. The measurement of MFC electrical power using the mudwatt app

The power measurement on the MFC was carried out to determine the effect of adding water spinach (K), mustard (S), spinach (B) waste on the performance of the MFC. The performance of the MFC in this measurement is the power generated from the LED flame. This measurement is carried out using the Mudwatt application on the mobile phone (Figure 2), which can identify the LED flame directly and determine the power value in microwatts.

2.3 Measurement of Current and Voltage by Polarization Method

A digital multimeter (Sanwa Digital Multimeter PC20) with series and parallel circuits was used to monitor MFC voltage and current. As shown in Figure 3, the two electrical quantities on the MFC are measured alternatively depending on the nutrients employed, with a resistor fluctuation of 10 Ω – 4.7 kΩ.

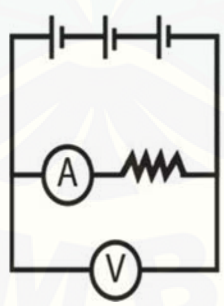

Figure 3. Measurement of Current and Voltage with the Polarization Method (A = Ammeter and V = Voltmeter)

The measurement results are then processed and calculated to obtain the value *power density* expressed in Mw/m^2. The calculation uses the equation:

$$Power\ Density = \frac{current\ (mA)\ x\ Volt\ (V)}{\text{anode surface area}} \left(\frac{\text{mW}}{\text{m2}}\right)$$

2.4 Measurement of pH

Measurement of pH using a Digital pH Meter 4 in 1 soil. Each MFC vessel was marked at a depth of 5 cm, then the pH meter probe was inserted until it touched the MFC soil and waited for the resulting value to be constant.

RESULTS AND DISCUSSION

3.1 Results of LED Power Measurements on MFC

The results of the daily electricity voltage monitoring measured for 42 days on both types of MFC are presented in Figure 4. It can be seen that all graphs show an upward trend in electric power until the 30 - 35th day, then the trend decreases. These phenomena indicate that biofilm formation on the anode surface is ongoing until sufficient food substrate is available. If this substrate is reduced, it will have an impact on microbial activity on the electrode surface and can even affect the survival of microbes. Another interesting event on the curve is that the electrical power generated by the MFC type added with vegetable waste has a greater value than the control MFC type.

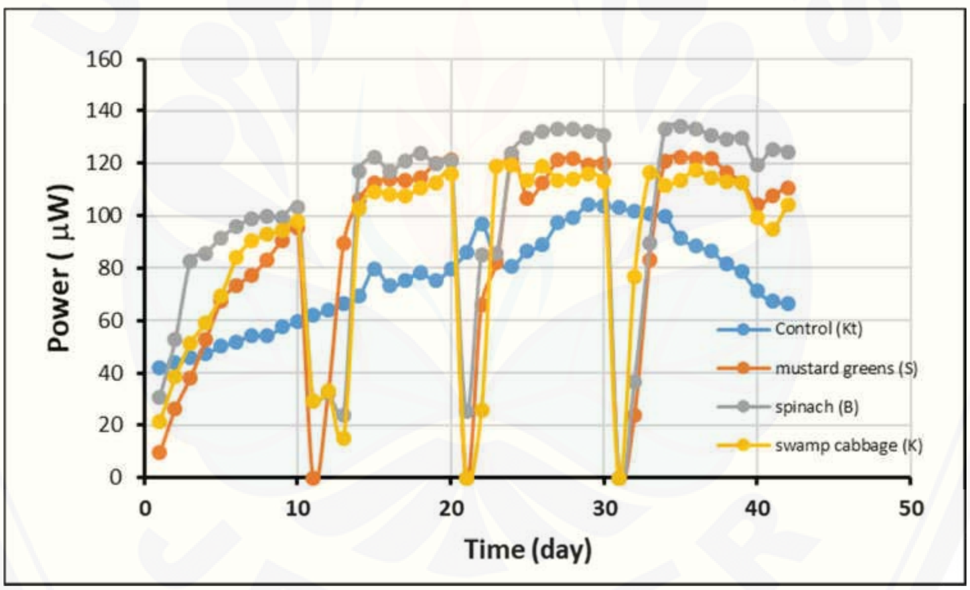

Figure 4. The results of the power measurement for 42 days

There is one more thing that needs to be revealed when the addition of vegetable liquid waste into the MFC soil media shows a very drastic downward curve until it does not produce electrical power for a while and then rises back to its original value position or even exceeds its original value. This sudden decrease indicates that the activity of microbial life is disrupted in the growth phase until these microbes adapt back to more food reserves. It is shown that the time of the microbial growth phase is longer than the growth phase of the control MFC.

In general, it can be said that the addition of vegetable waste in microbial living media can increase the electrical power of the MFC. The maximum value that can be achieved in this study is 134 uW found in MFC-B. While the values below are 122 uW and 110 uW, respectively, which are found in MFA-Kt and

MFC-S.In research [8], the peak voltage results are seen on day 50 of 330 mV at a ratio of a mixture of fruit and vegetables 75: 25. The difference in results obtained in this study was due to different methods and nutrients.

Research [8], used a system, *single-chamber* namely a plastic bucket with a volume of 12 liters, then the soil sample used was added with a variety of mixed ratios of vegetable and fruit waste. The distance between the electrodes is 50 mm. Measurements were carried out for 60 days and only measured the output voltage. Meanwhile, this study uses additional vegetable waste and uses a *chamber* with a volume of 500 mL, this is certainly one of the triggers for the difference in the results obtained. Microbes need time to adapt and reproduce with the surrounding environment, so it takes a long time to form a stable biofilm. Biofilm helps degrade organic compounds so that the electricity production in MFCs increases with the incubation time of the substrate. The incubation time that is too long will cause organic compounds that are on the substrate to always be degraded and cause the power generated to decrease because organic compounds will decrease continuously, and nothing else can be oxidized if no organic compounds remain [9]. The decrease in power occurs when the electrode surface is filled with biofilm, the number of electrons transferred to the electrode will be small so that the electrical energy produced is reduced. MFC efficiency and performance can be affected by various factors. The repeated cycle of adding nutrients results in better electrical energy production. The living environment in MFC research with mud soil as a substrate can be said to be an appropriate environment for microbial reducing organic matter as an electron producer.

3.2 Determination of maximum power using the polarization method

Graph 5 shows the value of power density power or maximum and current generated in each MFC. Type of MFC K produces a maximum power density of 131 mW/m^2 at a resistance of 100 ohms. MFC S produces a maximum power density of 156 mW/m^2 at a resistance of 50 and MFC B produces a maximum power density of 211 mW/m^2 at the resistance of 50, and MFC Kt produces a maximum power density of 75.1 mW/m^2 at a resistance of 30 ohms.

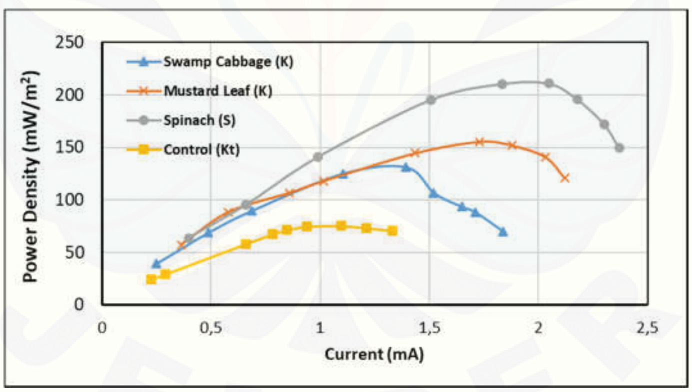

Figure 5. Graph of Current Relationship to Power Density generated by MFC

Graph 6 shows the value of the current and the resulting voltage for each MFC. The three MFCs that were treated with the addition of organic substrates produced an average voltage of 0.793 V. Meanwhile, the MFCs without treatment produced a voltage of 0.532 V. While the highest current was produced by MFC (B) of 2.37 mA. However, the MFC Kt (control) still produces the smallest electric current, which is 1.30 mA.

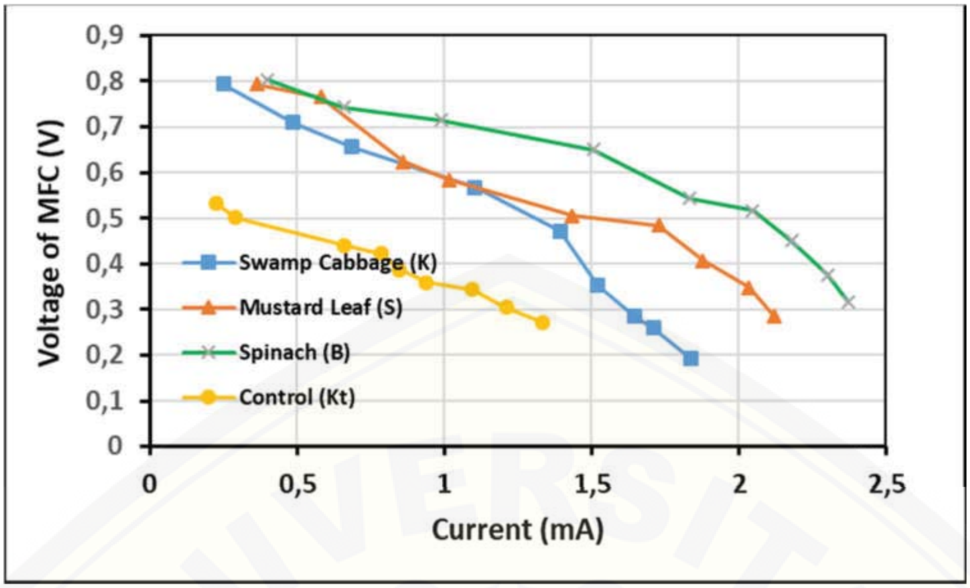

Figure 6. Graph of the relationship between Current and Voltage generated by MFC

Graph 7 shows the value of the current and the highest voltage generated at each MFC. The average current strength is 1.84 mA at MFC K and the highest average voltage is 0.793 V. At MFC S, the average current is 2.12 mA, and the highest voltage is 0.793 V.The average current strength is 2.12 mA at MFC S, and the highest voltage is 0.793 V. The average current strength is 0.793 V. is 2.37 mA at MFC B, and the highest voltage is 0.804 V. The current is 1.30 mA at MFC Kt, and the highest voltage is 0.532 V. These results can be seen in table 1.

Table 1. MFC measurement results in a series circuit

MFC	Power Density (mW/m^2)	Current (mA)	Voltage (volt)
MFC K	131	1,84	0,793
MFC S	156	2,12	0,793
MFC B	211	2,37	0,804
MFC Kt	75,1	1,30	0,532

The decrease in *power density* also occurs due to the activity of bacteria on the surface of the anode, which takes longer to form a biofilm, increasing the resistance on the anode surface and a decrease in the power density value [9]. Measurements of current and voltage sequentially from using the lowest resistance to a large resistance value show the value of the current strength decreases as the resistor value increases. The value of the voltage in this circuit increases as the resistance value of the resistor increases. The increase in the value of the voltage on the MFC is caused by an electrochemical process whose speed increases and is associated with the activity of breaking down organic materials by bacteria until the metabolic rate is stable [10]. The magnitude of the voltage value is also because in the series circuit the total value of the resistor or resistance (R) is the sum of each resistance of the voltage source, which in this study the MFC is the voltage source. The resistance value is inversely proportional to the current strength so that the current strength value decreases as the resistor value increases.

The results of this study indicate that the optimum value of *power density* for MFC B is 211 mW/m^2, the average voltage is 0.804 V and the average maximum current is 2.37 mA. The addition of microbes through EM_4 will affect the measurement results. The use of a larger area for bacterial contact in transferring electrons to the electrodes can affect the energy produced and affect the results *power density*[11]. The length of storage in MFC research will also affect the energy produced by microbial activity so that the provision of nutrients for microbial survival or metabolism is necessary.

The repeated cycle of adding nutrients results in better electrical energy production. The living environment in MFC research with mud soil as a substrate can be said to be an environment suitable for microbial reducing organic matter as an electron producer[12].

3.3 Results of Soil pH Testing

The pH of the MFC soil media was measured every day for 20 days [9]. The incubation time of MFC can affect the resulting pH value because each room in the MFC has a different living environment for microorganisms so that the pH value depends on the environmental conditions and the metabolic processes of the microorganisms.

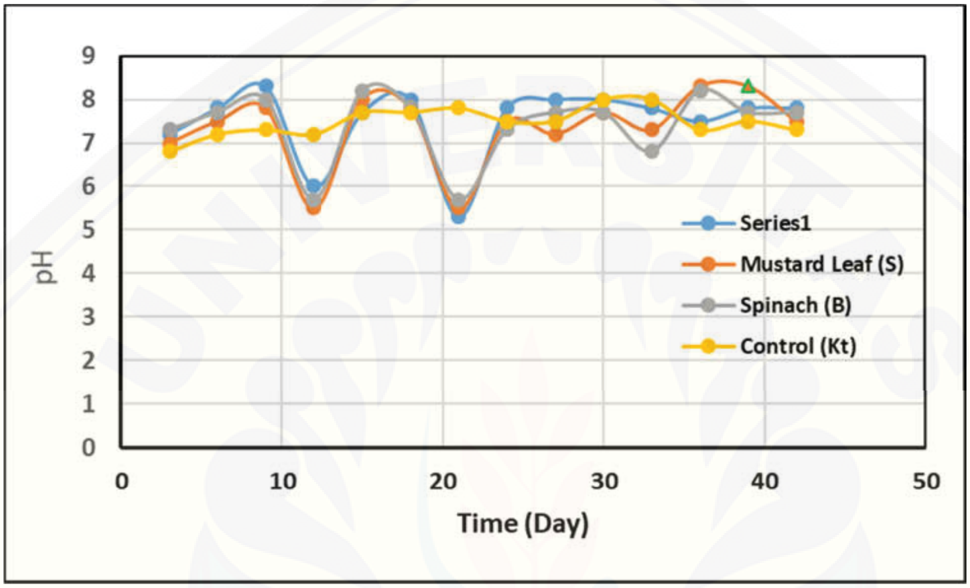

Figure 7. Graph of Effect of MFC Incubation Time on pH

When microbes adapt to their environment after adding nutrients, pH shows a low value under acidic conditions. Then the pH value will gradually show a neutral value on the next day's measurement, and can also reach an alkaline value as shown in figure 7. . The increase in pH value can be caused by a decrease in the amount of oxygen used by bacteria when decomposing organic matter. The pH will decrease due to the presence of Hions^{+} resulting from bacterial metabolic processes in the anode chamber (substrate environment), the presence of H^{+} can affect the pH conditions on the cathode side[13]. Optimum bacteria live at pH 7-9, if the pH shows a number below five or more than nine, the bacteria do not work optimally.

The power produced is also affected by the pH of the soil media, to find out this measurement is carried out on one of the MFCs with nutrient B.

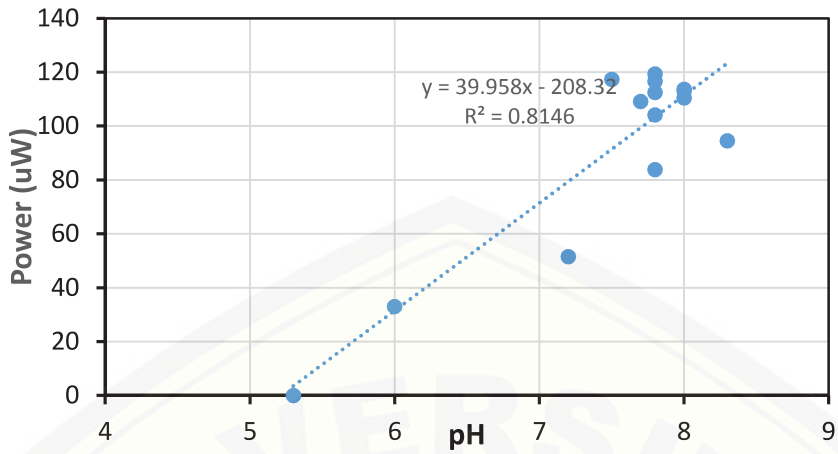

Figure 8. Graph of the effect of pH on Power The

The power generated depends on the pH value, if the power generated is small or the LED on the MFC low pH value that is under acidic conditions. The optimum pH for bacterial growth is between 6.5 – 8 and a maximum pH of 8.3. Shifts in pH in a medium can occur due to acidic or alkaline compounds during the microbial breeding process. The graph of the relationship between pH power and MFC B power produces a linear regression equation, namely, y = 39.926x - 191.43 where x is the resulting pH and y is the MFC B power. Based on Figure 8, the effect of pH on power, the graph produces a line linear regression. The correlation coefficient value indicated by R = 0.803 indicates that the pH value and power have a fairly strong relationship according to a linear relationship.

The catalyst in the MFC system can accelerate the occurrence of chemical reactions for the growth and function of microorganisms. Catalysts can be in the form of organic acids, proteins, and carbohydrates contained in the nutrition of vegetable waste given to the MFC system. Spinach has a carbohydrate content of as much as 6.5 g; and 3.5 g of protein. Kale vegetables contain carbohydrates as much as 5.63 g; and 1.9 g of protein [14]. Then the mustard greens have carbohydrates as much as 3.9 g; and 1.8 g of protein [15]. Microbes need time to adapt and reproduce with the surrounding environment, so it takes a long time to form a stable biofilm. Biofilm helps degrade organic compounds so that the electricity production in MFCs increases with the incubation time of the substrate. Incubation time that is too long will cause organic compounds that are on the substrate to always be degraded and cause the power generated to decrease because organic compounds will decrease continuously, and nothing else can be oxidized if no organic compounds remain [9].

CONCLUSION

The addition of vegetable waste to the MFC has a significant impact on the electricity generated. The MFC with spinach waste had the highest electrical power value. A power of 134 W was achieved on the 35th day. The MFC Kt power value (control) was lower than the average MFC in the presence of vegetable waste nutrients. At MFC B, the maximum power density produced by a series circuit is 211 mW/m2, the average voltage is 0.804 V, and the maximum current strength is 2.37 mA.

The incubation time of MFC affects the pH value of the soil medium. so the pH value is different on the first day of measurement from the next day. The pH of the soil media affects the value of the power produced by the MFC.

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