

## **The effect of composition and substrate fermentation duration on microbial fuel cell electrical energy**

Christin Vera Natalia Ginting<sup>1,\*</sup>, Jumaida Sari Nasution<sup>1</sup>, Malik Alfatah Sembiring<sup>2</sup> and Murniaty Simorangkir<sup>1</sup>

<sup>1</sup>Department of Chemistry, Universitas Negeri Medan, Medan 20221, Indonesia

<sup>2</sup>Department of Physics, Universitas Negeri Medan, Medan 20221, Indonesia

\*Corresponding author: (CVNG), [christinginting21desember@gmail.com](mailto:christinginting21desember@gmail.com)

DOI: 10.24114/jpkim.v11i3.15773

Received: 11 July 2019; Accepted: 29 October 2019

### **Abstract:**

Organic vegetable wastes such as mustard vegetables found in traditional markets, especially Medan, are quite abundant and the increase in electricity demand is not matched by the availability of adequate energy sources, encouraging efforts to find alternative sources of renewable energy, economical and environmentally friendly. Microbial Fuel Cell (MFC) reactors can be used as an alternative energy source that converts chemical energy into electrical energy through biocatalytic reactions using microorganisms by utilizing organic materials. This study aims to determine the effect of the use of mustard vegetable waste substrate with a variety of starters and fermentation duration in the MFC reactor system to the voltage and current of electrical energy generated. The design of this study used a factorial 4x2 Completely Randomized Design consisting of two factors, namely factor A substrate composition and fermentation duration B factor. The results showed that there was an influence of substrate composition and fermentation duration on the MFC reactor system on the electrical energy generated by the system. Electricity (I) (20.1 mA) and voltage (72.13 mV) highest electricity produced by MFC reactor with composition of glucose substrate and EM4 starter with 5 days fermentation duration, followed by the treatment of vegetable mustard waste and EM4 with a fermentation duration of 5 days (15.2 mA and 68.76 mV). In terms of economics, the use of vegetable mustard waste substrate material with EM4 starter in the MFC reactor has more potential to be developed than using glucose substrates which are relatively more expensive.

**Keywords:** Electric energy; fermentation duration; microbial fuel cell; mustard vegetable waste

### **Introduction**

The abundance of organic waste such as vegetable waste such as mustard vegetables found in traditional markets, especially Medan. Can pollute the environment if it is disposed of carelessly.

In addition to the problem of waste, energy problems are also one of the problems that are often faced in the city of Medan. Increasing energy demand continues to increase but is not balanced with the availability of adequate energy sources. Therefore, a sustainable alternative energy source is needed to avoid an energy crisis. The Microbial Fuel Cell (MFC) reactor can be used as an alternative energy source that is environmentally friendly and can be a source of energy in the future (Chang et al. 2016a; Padey et al. 2011). MFC can convert chemical energy into electrical energy through biocatalytic reactions, which use microorganisms. MFC facilitates an oxidation reduction environment that can be controlled by the flow of electrons and makes it an ideal tool for processing organic matter into inorganic matter in microbial waste. Transfer

mechanism electrons in the MFC anode are the main issue in understanding the theory of how MFC works (Liu and Logan, 2004). Microbes move electrons through an electron transport system consisting of a series of components of the bacterial extracellular matrix or together with the transfer of electrons dissolved in a mass solution (Chang et al. 2006b; Padey et al. 2011).

The use of microorganisms in biofuel cells can eliminate the isolation of individual enzymes so as to provide a cheaper substrate for fuel cells. Electricity has been produced using energy sources for complex needs of wastewater (Scott et al. 2007). Bacteria in MFC can be used to produce electricity while consuming waste (Romadhoni and Putu, 2014). Manufacture of alternative energy (biogas) can also use mustard vegetable waste mixed with livestock manure (Sari et al. 2015). Vegetable mustard is one type of vegetable that is widely marketed in the city of Medan and is the most common vegetable waste found in traditional market markets in the city of Medan. This vegetable mustard waste contains organic substances which can be described by fermentation by microbes. This study aims to determine the effect of the composition of the vegetable mustard waste substrate with starter manure, fermentation time, and its interaction using the MFC reactor system to the voltage and current of electrical energy produced system. The results of this study are expected to provide information to the people of Medan regarding the use of vegetable waste as raw material to produce electricity by using a reactor system Microbial Fuel Cell (MFC) as one of the alternative sources of renewable energy and environmentally friendly.

## **Materials and Methods**

### ***Materials and chemicals***

The tools used in this study are MFC reactors (acrylic chamber, Nafion 121 membrane, graphite electrode), Masda 830B AVOMETER digital multimeter, Basic meter (HERMA), cable, alligator clamp, lamp and nest, glass beaker and glass stirrer.

The materials used in this study are vegetable mustard waste from the traditional market MMTC and Medan Sambu, Cow Dung, Electrodes (graphite), Nafion 121 membrane, Aquades, NaOH 1M, HCl 1M,  $\text{KMnO}_4$  1M, phosphate buffer 0,1 M, cling wrap, Aluminum foil, Glucose 1M, EM4 bacteria,  $\text{H}_2\text{O}_2$  3%,  $\text{H}_2\text{SO}_4$  1M.

### ***Membrane preparation***

The membrane used in this study was 121 breaths which were first boiled with distilled water for 1 hour, then boiled with  $\text{H}_2\text{O}_2$  3% for 1 hour and washed with distilled water. The membrane was then boiled back with  $\text{H}_2\text{SO}_4$  1M for 1 hour then washed with distilled water 3 times. The membrane is stored (soaked) in distilled water until it will be used (Scott et al. 2007).

### ***Electrode preparation***

Graphite electrodes were soaked in HCl 1M solution for 1 day then rinsed with distilled water, after that the electrodes were soaked again into NaOH 1M solution for 1 day then rinsed again using distilled water. The electrode is soaked in distilled water solution until it will be used (Purwonoet et al. 2015).

### ***Substrate and stater preparation***

The substrate of vegetable mustard trash is cut into pieces and weighed as much as 200 gr. As much as 100 grams of mustard pieces are mixed with starter of cow dung and 100 grams of mustard pieces mixed with EM4 starter, then added with water and stirred, then let stand.

Substrate of glucose 1M solution was made by dissolving 40.54 g of glucose in 226 mL of distilled water. A total of 113 mL of glucosal solution was mixed with cow manure stater and 113 mL of glucose solution mixed with the EM4 bacteria stater, then water and stirred in each mixture then let stand.

**Electrolyte preparation**

The electrolyte used is a potassium permanganate (KMnO<sub>4</sub>) 1M solution by dissolving 71.8 grams of KMnO<sub>4</sub> in distilled water to a solution volume of 450 mL.

**Experiments of variations in substrate composition, status and duration of micro-fuelcell fractionation**

Provided 4 sets of MFC reactors. In the anode compartment each reactor is filled with a mixture of mustard substrate and stater cattle dung, a mixture of mustard and EM4 bacteria, a mixture of glucose and cow dung, a mixture of glucose and EM4 bacteria. phosphate buffer solution added. Each experiment variations on substrate composition and stater were repeated 3 times. In each experiment a measurement of the electrical energy produced by the MFC reactor (electric current (I) and voltage (V) at the time after 5 days of fermentation and after 10 days of fermentation with the Masda 830B AVOMETER Digital Multitester.

**Measuring the current and voltage strength of the MFC electrical energy system**

The current strength of the MFC system is measured using a Basic meter (HERMA) and the voltage of the MFC system is measured using the Masda 830B AVOMETER Digital Multitester.

**Data analysis**

Data analysis was performed with factorial 4x2 ANOVA with repeated 3 times.

**Results**

**Electric energy produced by microbial fuel cell system**

Electrical energy (strong current I and voltage V) produced by MFC reactor systems made from mustard and stater vegetable waste that varied and long periods of 5 and 10 days fermentation are presented in [Table 1](#) and [Table 2](#).

**Table 1**

Strong electric energy flow of MFC system variation in substrate composition and duration of fermentation

Factor B Duration of Fermentation	Factor A Substrates and Stater Composition			
	A1 (Garbage mustard + cow dung)	A2 (Garbage + EM4)	A3 (Glucose + cow dung)	A4 (Glucose + EM4)
	I (mA)	I (mA)	I (mA)	I (mA)
5 days	5.18	15.2	8.0	20.1
	5.12	15.2	7.9	20.1
	5.12	15.2	8.0	20.1
Average	5.14	15.2	7.93	20.1
10 days	1.51	5.3	4.1	8.24
	1.44	5.3	3.8	8.20
	1.50	5.3	4.0	8.20
Average	1.48	5.3	3.39	8.21

**Table 2**

Electric energy voltage microbial fuel cell system variation in substrate composition and duration of fermentation

Factor B Duration of Fermentation	Factor A Substrates and Stater Composition			
	A1 (Garbage mustard + cow dung)	A2 (Garbage + EM4)	A3 (Glucose + cow dung)	A4 (Glucose + EM4)
	V (mV)	V (mV)	V (mV)	V (mV)
5 days	27.01	68.8	42.3	72.1
	26.88	68.7	42.4	72.2
	27.00	68.8	42.3	72.1
Average	26.96	68.76	42.3	72.13
10 days	5.2	23.2	10.6	35.0
	5.1	23.3	10.7	34.9
	5.2	23.3	10.6	34.9
Average	5.15	23.27	10.63	34.9

The results of factorial ANOVA analysis using the SPSS program for electrical energy data (Flow) from the Microbial Fuel Cell reactor are presented in Table 3. and the voltage (Volt) is presented in Table 4.

**Table 3**

ANAVA electric current

Dependent Variable: Ampere\_Value

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	813.244 <sup>a</sup>	7	116.178	31153.800	.000
Intercept	1702.019	1	1702.019	456407.286	.000
composition	410.233	3	136.744	36668.864	.000
lama_fermentation	325.091	1	325.091	87175.295	.000
composition *	77.920	3	25.973	6964.905	.000
lama_fermentation					
Error	.060	16	.004		
Total	2515.323	24			
Corrected Total	813.304	23			

**Table 4**

Electric voltage ANAVA

Dependent Variable: Volt\_Value

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	12770.023 <sup>a</sup>	7	1824.289	510886.062	.000
Intercept	30287.905	1	30287.905	8482026.932	.000
composition	5368.911	3	1789.637	501181.876	.000
lama_fermentation	6956.075	1	6956.075	1948025.532	.000
composition *	445.038	3	148.346	41543.758	.000
lama_fermentation					
Error	.057	16	.004		
Total	43057.985	24			
Corrected Total	12770.080	23			

ANOVA test results (Table 3 and Table 4) show that the substrate composition and fermentation time affect the electric current and voltage (voltage) of electrical energy produced by the Microbial Fuel Cell (MFC) reactor with variations in the composition of vegetable mustard and glucose waste substrates, dirt stater cattle and EM4 with a fermentation period of 5 days and 10 days. The highest electric energy flow (20.1 mA) and the highest voltage (72.13 mV) produced by MFC reactor with glucose substrate composition, EM4 starter with 5 days fermentation time, followed by treatment of mustard trash substrate composition, EM4 starter with 5 days fermentation time. The longer the fermentation process, the current and voltage of the electrical energy produced by the MFC system decreases (Scott *et al.*, 2007). Even so, in terms of economics, the use of vegetable mustard waste substrate material with EM4 starter in the Microbial Fuel Cell (MFC) reactor has the potential to be developed compared to using glucose substrate materials whose prices are relatively more expensive. The Microbial Fuel Cell (MFC) reactor made from substrate of vegetable mustard waste with EM4 starter has the opportunity to be developed as a source of renewable alternative energy, economical and environmentally friendly, both in cities and in rural areas, especially those that lack electricity supply.

## **Discussion**

Microorganisms can change chemical energy stored inside organic components into electrical energy during incubation in Microbial Fuel Cell (MFC), so that bacteria inside MFC can be used to produce power electricity while consuming waste (Romadhoni and Putu, 2014). Womb degradation process organic in order to produce liquid waste, this bio-electricity certainly requires microbes parser. Ibrahim *et al.* (2017) reported that MFC modeling uses activated sludge in fishery wastewater can be applied to produce bio-electricity. Microbial content in the mud active can be used on the MFC system to produce electrical energy through the process of destroying compounds organic (Silaban and Simamora, 2018). Active mud is an ecosystem which is a complex consisting of bacteria, protozoa, viruses, and organisms other. The activated sludge is usually consists of a combination of decomposing bacteria e.g. *Aerobacter sp.*, *Nitrobacter sp.*, *Nitrosomonas sp.*, And bacterial strains other decomposers who are able to degrade organic content for example accelerates fermentation process of dissolved organic waste in water and reduce the content organics in wastewater. Utilization activated sludge is also expected to be able to used on MFC systems, so besides degrade organic content in fisheries liquid waste, use of mud the active can also produce bio-electricity. Electrical data generated using types of graphite plate electrodes and rods graphite is 0.5-0.6 volts, then as an effort utilization, fisheries industry wastewater this can be used as a deep substrate MFC system for electricity production.

Utilization of industrial wastewater fisheries in the MFC system are expected can be an alternative waste treatment which has been used and can overcome the main problems caused by wastewater, that is odor that is not delicious which causes discomfort to the surrounding community. Results of research this is also expected to be wrong one step ahead to get new and renewable energy sources, so use of MFC systems with water substrat waste can reduce energy consumption fossils (Du *et al.* 2007; Nasution and Silaban, 2017). Waste water treatment using Anaerobic biofilter is a technology inexpensive processing, easy operation and saving energy. Technology concept processing with anaerobic biofilter is a term from the developed reactor with the principle of microbes growing and developing stick to a filter media (media attached) and form a biofilm (attached growth). Biofilter can be used for water waste with a large COD load and can remove suspended solids (SS) well (Wijeyekoon *et al.* 2004).

## Conclusion

Substrate composition, temperature and duration of substrate fermentation and interaction of substrate composition with fermentation duration in the Microbial Fuel Cell (MFC) reactor system affect the electrical energy produced by the system. The highest electrical current (20.1 mA) and voltage (72.13 mV) is produced by the MFC reactor with the composition of the glucose substrate, EM4 starter with a 5 day fermentation period, followed by the composition of the mustard vegetable waste substrate, EM4 starter with fermentation time of 5 days (15.2 mA and 68.76 mV). The Microbial Fuel Cell (MFC) reactor made from vegetable mustard waste substrate with EM4 starter has the opportunity to be developed as a source of renewable alternative energy because it is relatively cheaper compared to using glucose substrates.

## Acknowledgments

Thank you to the Ministry of Research, Technology and Higher Education Simbelmawa for the 2018 PKM grant that has been given for the implementation of the PKM-PE that has been implemented.

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