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Voltage Output Generated by Dry Yeast Cells in Microbial Fuel Cells

Marilyn Palomado Mifuel

West Visayas State University, General Luna Street, La Paz, Iloilo City 5000, Philippines

ABSTRACT

A microbial fuel cell (MFC) or "bio-battery" is a bio-electrochemical device that can generate electricity by the use of electrons obtained from the anaerobic oxidation of substrates. The microorganisms metabolize the substrates at the anode compartment, during which process protons, electrons and carbon dioxide are released. The electrons are transferred from anode chamber to cathode chamber employing an external electrical circuit to generate electrical energy. This study aimed to determine the voltage output of dry yeast cells fed with raw sugar as substrate. The H-shaped MFC design was used due to its simplicity and low cost. With the same amount of raw sugar as substrate, the amount of dry yeast cells were progressively increased. Three (3) treatments were prepared with (3) replicates per treatment. The voltage output was measured every hour for 24 hours. The mean was used to describe the voltage output while the One Way ANOVA was utilized to determine the significant difference in the voltage output per treatment. . Results showed that the average voltage output of Treatment 1 is 0.191V, 0.277 V in Treatment 2 and 0.775 V in Treatment 3. It was also found out that there is a significant difference in the mean voltage outputs of the MFCs with different amount of dry yeast cells. Hence, amount of yeast significantly affect the voltage output generated in the microbial fuel cells.

Keywords: Microbial fuel cell, voltage output, substrate, anode, cathode, oxidation, reduction

I. Introduction

With the rise of costs of fuels, scientists are looking for alternative source of fuels. The demand for alternative energy sources has increased due to variety of environmental conditions, the use of bioenergy or biofuels has been one focus. Compared to renewable resources which use the power of the environment, biofuel uses bioactivity as fuel source. (Hintz et al, 2003). One source that they are looking into are microbial fuel cells (MFC). Although this technology is not new, advancements and new discoveries are showing that this technology may have promising applications. A widely used design is the H-shaped design as it is inexpensive and can be easily constructed (Logan, et al, 2006). The electricity generated by MFC is efficient and environment -friendly with little or no carbon emissions, hence a bio-battery. An MFC is a system in which microbes convert chemical energy produced by the oxidation of organic/inorganic compounds into ATP by sequential reactions in which electrons are transferred to a terminal electron acceptor to generate an electrical current (Torres et al. 2009). A microbial fuel cell (MFC) is a bio-electrochemical device that can generate electricity by the use of electrons obtained from the anaerobic oxidation of substrates. Generally, the MFC consists of two parts, an anode and a cathode, which are separated by a proton exchange membrane (PEM). Anaerobic oxidation of organic substances such as acetate, glucose, lactate, ethanol (summarized by Pant et al., 2010) occurs in the anode compartment, during which process protons, electrons and carbon dioxide are released. In this case, the protons and electrons pass through the anode chamber to the cathode chamber via the PEM and an external circuit respectively. This electron transfer from the anode to the cathode produces an electricity current (Logan et al., 2006; Venkata Mohan et al., 2008; Kim and Lee, 2010; Mao et al., 2010; Samrot et al., 2010; Ishii et al., 2013).

MFC have many advantages as compared to conventional cells. It can consume almost any type of organic waste to convert as fuel. Most of the fuels needed by microbes are in the form of sugars and starch which are more readily available than conventional fuel. Yeasts are eukaryotic, single-celled microorganisms classified as members of the fungus kingdom. Yeasts have two main uses in food production: baking and making alcoholic beverages. They have been used in this way since ancient times. Yeast is safer to use than other bacterial cultures as it is non-toxic and environment-friendly. In addition, they are accessible, and easy to handle. Despite promising initial results of the studies on MFCs, it has not been able to go further than the pilot scale due to a number of limitations (Liu and Logan, 2004; Donovan et al., 2011). The power output of the MFC depends on several factors such as type of substrate, exoelectrogenic microorganisms, circuit resistance, electrode material, reactor configuration and electron acceptors (Pant et al., 2010; Kim et al., 2011). Different electron acceptors exhibit physically and chemically different properties (e.g., oxidation potential) and therefore affect the efficiency of electricity production. Therefore, further investigation along these lines must be conducted.

1.2. Statement of the Problem

This study aims to ascertain the potential of using dry yeast as microbes and raw sugar as substrate in Microbial Fuel Cell

Specifically, this study sought to answer the following questions:

1.2.1 What is the voltage output of MFC that contains different amount of dry yeasts?

1.2.2 Is there a significant difference in the voltage output of the MFC that contains different amount of dry yeast?

1.3. Theory and Concepts

1.3.1 Working Principles Behind MFCs

Microorganisms are everywhere, they feed on organic substrate such as sediments, wastewater, sludge, manure from livestock, sugars, etc. As foods for microbes, organic substrate undergo bio-catalytic activity or chemical transformations. The process has double effects: treatment or stabilization of products and direct generation of electricity. The figure below summarizes the concept.

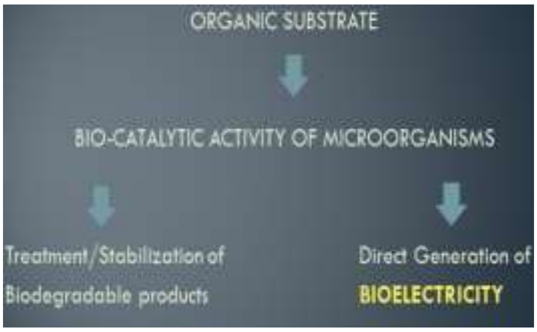

Figure 1. Production of energy from organic matter

As a system, MFC generally has one anode chamber (negative electrode) and one cathode chamber (positive electrode). MFC works in a similar way to batteries. The working of microbial fuel cell (MFC) technology is based on the principle of **redox reactions**. The bacteria/microbe oxidize the organic matter to produce carbon dioxide (CO_2), electrons, and protons. The natural metabolism of the microbes is utilized to generate **electricity.** Oxidation occurs at the anode and reduction occurs at the cathode. The chemical reaction is represented below.

ANODE (Organic Substrate Oxidation)

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

CATHODE (Oxygen reduction)

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

Microorganisms decompose organic or inorganic matters (or substrates) in the anode chamber to produce electrons. These electrons flow from anode to cathode via an external circuit made of conductive materials, such as copper-based wires, to generate electricity. Anaerobic oxidation of organic substances such as acetate, glucose, lactate, ethanol (summarized by Pant et al., 2010) occurs in the anode compartment, during which process protons, electrons and carbon dioxide are released. In this case, the protons and electrons pass through the anode chamber to the cathode chamber via the PEM or salt bridge and an external circuit respectively. This electron transfer from the anode to the cathode produces an electricity current (Logan et al., 2006)). The figure below summarizes how the MFCs operate.

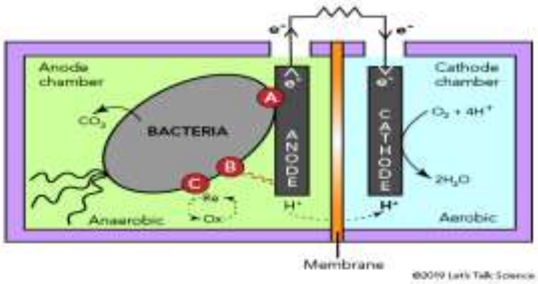

Figure 2. Redox reactions in MFC

II. Materials and Methods

2.1 Materials

2.1.1Dry Yeast Activation

Dry yeast cells

Distilled water (lukewarm)

Raw sugar

Measuring cups

Measuring spoon

Digital weighing scale

Beakers

Digital Thermometer

Warm water

2.1.2. H-shaped MFC

Plastic containers

Garden hose

Electrical tape

Cotton cloth

Salt

Copper wire

Electric drill

Alligator clips

glue gun with glue stick

Digital voltmeter

Steel screen

watch

scissors

2.2 Procedure

2.2.1 Salt Bridge Preparation

Cut the garden hose to 4 inches long

In 500 mL water, add 50 g table salt. Place the cotton rope/cloth in the

solution. Boil for 10 minutes. Set aside for 10 minutes to let it cool

Place the cotton rope inside the garden hose. Make sure the rope tightly fits inside the hose

2.2.2 MFC Assembly

Drilling Operation

Drill a hole for the copper wire in the lid of each container. In one lid drill two more holes for ventilation; this is your cathode container, the other container is the anode.

Drill a bigger hole on the side of each container for the salt bridge.

Attach the prepared salt bridge on each side of the container.

Seal the junction of the container and salt bridge using the glue gun

Putting the Electrodes in Place

Fold the steel screen into 1”X3“ rectangular shape.

Strip the ends of two pieces of copper wire and attach each to the steel screen

Insert one electrode into each hole in the container lids (anode and cathode) then seal with hot glue.

2.2.3 Yeast Activation…getting ready for work

At the anode, place 10 g of sugar. Add measured amount of yeast. (based on the treatment). Place 800mL of lukewarm water (38^0C) in the anode container. Stir to dissolve both sugar and yeast. Seal the container with electrical tape.

At the cathode, place 800 mL of distilled water. Cover the container.

2.2.4 Measuring the Voltage Output

Set the digital voltmeter to the desired unit. Connect the alligator clips to the designated anode and cathode electrodes of the MFC. Read and record the voltage output registered in the digital voltmeter every hour for 24 hours.

III. Results and Discussion

3.1. Findings

To find out the voltage output generated by different amount of dry yeast cells fed with the same amount of raw sugar, an experiment was actually conducted by the researcher last May 13-14, 2022. The experiment is composed of three (3) treatments with the same amount of raw sugar (10g) but with progressively increasing amounts of dry yeast cells at 5g, 10g and 15g. Each treatment has three (3) replicates.

Voltage Output Generated by Varying Amount of Dry Yeast Cells

The table below shows the mean voltage output generated by dry yeast cells in MFCs. Treatment 1(5 g yeast) with voltage reading of 0.1913V, Treatment 2 (10g yeast) with 0.2767V and Treatment 3 (15g yeast) with 0.7767V. As shown in the table, Treatment 3 has the highest voltage output while Treatment 1 has the lowest. It also shows that there is a close mean difference in voltage reading between Treatment 1 and 2; however, a larger mean difference between Treatment 1 (2) and Treatment 3 is notable.

Table 1. Voltage output generated by different amount of dry yeast cells

Descriptive

YEAST	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
5 G	24	0.1913	0.01727	0.00353	0.184	0.1985	0.16	0.22
10 G	24	0.2767	0.03212	0.00656	0.2631	0.2902	0.21	0.32
15 G	24	0.7767	0.1137	0.02321	0.7287	0.8247	0.42	0.89
Total	72	0.4149	0.26875	0.03167	0.3517	0.478	0.16	0.89

The figure below shows the mean voltage output per hour in 24 hours of Treatments 1,2, and 3. Based on the graph, Treatment 1 produced the least voltage output and Treatment 3 has the highest voltage reading. It is notable that the voltage readings in Treatment 1 and 2 are almost the same or consistent in 24 hours. However, in Treatment 3, an increasing trend in voltage output is noteworthy. Likewise, the voltage reading per hour in 24 hours of the three (3) treatments vary with one another. This could be attributed to the amount of dry yeast cells placed at the anode with Treatment 3 on the lead. The control has no voltage output.

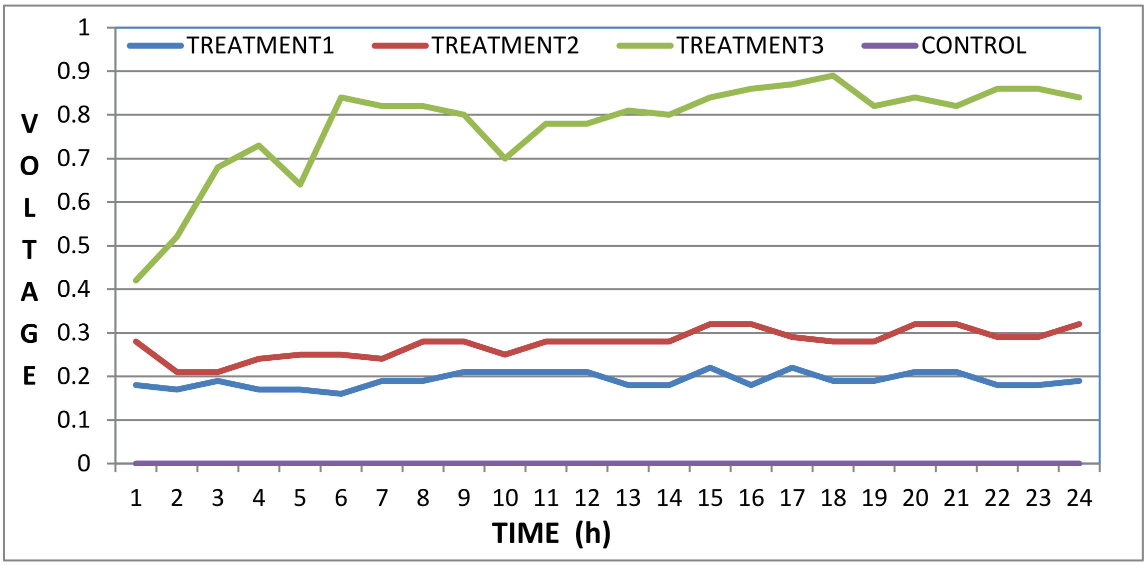

FIGURE 1. Mean Voltage Output Generated by different amount of dry Yeast Cells in MFC Treatments 1,2,3.

The difference in the Voltage Output of Different Amount of Dry Yeast Cells in the Different Treatments

The difference between the voltage output of the three treatments are shown in Table 2. As shown in the table, a very high F-value (504.994) indicates that there is a significant difference between the voltage outputs generated by dry yeast cells in Treatments 1,2,3. This is supported by ANOVA result (sig.=.000) indicating that equal variances are not assumed. Hence a post hoc test is done. Table 3 shows the result of the multiple comparisons. Based on Table 3, there is a significant difference in the voltage outputs of the three (3) treatments (sig= .000) at α .05 level.

Table 2. **Test of Difference in the Voltage Outputs of Treatments 1,2,3.**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.8	2	2.4	504.994	0.000
Within Groups	0.328	69	0.005		
Total	5.128	71			

Table 3. Multiple Comparison Test Results (Scheffe)

Multiple Comparisons

Scheffe

(I) YEAST02		(J) YEAST02		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
dimension2	5 G	dimension3	10 G	-.08542*	0.0199	0.000	-0.1352	-0.0356
			15 G	-.58542*	0.0199	0.000	-0.6352	-0.5356
	10 G	dimension3	5 G	.08542*	0.0199	0.000	0.0356	0.1352
			15 G	-.50000*	0.0199	0.000	-0.5498	-0.4502
	15 G	dimension3	5 G	.58542*	0.0199	0.000	0.5356	0.6352
			10 G	.50000*	0.0199	0.000	0.4502	0.5498

*. The mean difference is significant at the 0.05 level.

IV. Conclusion

Based on the results of this study, the following conclusions were advanced:

1. Dry yeast cells has the potential to generate consistent voltage output in Microbial Fuel Cells.
2. There is a significant difference in the voltage output generated by different amount of dry yeast cells
3. The amount of dry yeast cells has an effect on the voltage output generated in the Microbial Fuel Cells.
4. The more yeast cells are used, the more voltage output is generated

V. Recommendations

In the light of the foregoing findings and conclusions, the following are recommended for future researchers interested with MFCs:

1. Use dry yeast cells with amount of 15 g or higher to produce notable voltage outputs
2. Connect the MFCs in parallel or in series in order to generate higher and serviceable voltage output.
3. Design a more sophisticated MFC with appropriate electrodes for redox reaction to progress steadily and spontaneously.
4. Standardize the Microbial Fuel Cells

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