Research Article

Journal of Medical - Clinical Research & Reviews

Lightning in a Bottle: Harnessing Bioelectrogenesis in Microbial Fuel Cells for Electrical Generation

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Received: 04 June 2018; **Accepted**: 29 June 2018

Citation: Tanner Ash, Elizabeth Doyle, Godfrey Ssenyonga, et al. Lightning in a Bottle: Harnessing Bioelectrogenesis in Microbial Fuel Cells for Electrical Generation. J Med - Clin Res & Rev. 2018; 2(3): 1-3.

ABSTRACT

Bioelectrogenic microorganisms offer an attractive alternative for generating electricity when traditional methodologies are impractical. Coupled with a fuel cell, these microorganisms provide a potentially auspicious source of renewable energy. A microbial fuel cell was constructed and tested in laboratory and field-based conditions. Preliminary experimentation shows promising results and demonstrates the practical utility of this renewable energy source.

Keywords

Microorganisms, Microbial fuel cell, Alternative energy, Synthetic biology, Bioelectrogenesis, Renewable energy.

Introduction

Despite the worldwide spread of electricity that propelled the late Industrial Revolution in the late-nineteenth and early-twentieth centuries, many regions of the world still lack access to electricity. Less than 20% of the populace has access to electricity in many countries (e.g. Tanzania, Niger, Sierra Leone, Burkina Faso, Central African Republic, Liberia, Malawi, Burundi, Chad, South Sudan etc.) (World Atlas, 2017). This disparity substantially inhibits social and economic growth since electricity has become an essential element of modern life. Electricity is a highly valuable utility in the industrialized world which is used for - but not limited to - lighting, medicine, refrigeration, and computing. The availability of electricity for these applications is even more important in emergency situations (e.g. natural disasters, military conflicts, etc) when traditional electric sources may not be available. Given the critical role of electricity to adequately address and resolve emergency situations, it is imperative to investigate alternative methods for electrical generation. Bioelectrogenesis offers a promising means of addressing this issue.

Bioelectrogenesis utilizes biological processes to generate electricity. While the most well-known example of bioelectrogenesis is found in the electric eel, many soil-based bacterial species are also capable of generating electricity. These bioelectrogenic microorganisms can be coupled with electrodes to create microbial fuel cells (MFC). Cellular respiration causes electrons to be emitted from bioelectrogenic microbes. MFCs utilize these electrons to complete an electrical circuit. Electron flow (i.e. electrical current) between the electrodes of the MFC can be used to power an electrical device.

In light of the ready availability of microbial energy sources, this technology has the potential for widespread utility with a variety of applications. Specifically, it would be highly valuable for providing electricity in emergency situations. A MFC device can readily be constructed from inexpensive materials. Construction of a MFC requires cultivation of a diverse microbial population with several microbial species that are known to be bioelectrogenic. The bacterial genus Shewanella is commonly found around the world. The anaerobic bacterial Geobacter genus is located in deep soil underground or in ocean sediments. While Protozoa are not specifically bioelectrogenic, this common eukaryotic class plays an essential role to balance the ecological environment necessary to support a bioelectrogenic population. Sufficient nutrients must also be present in the environment to cultivate a microbial population. These include carbohydrates and organic nutrients found in soil, which are consumed by microbial cellular respiration and produce electrons. These electrons are then released back into the soil, which can be used in an electrical circuit to power a device. This work focused upon the taking advantage of the properties of bioelectrogenic microorganisms to generate power in emergency situations.

Materials & Methods

Two standard beakers and two plastic containers
Two Zinc strips and Two Copper strips.
Electrodes – Anode and Cathode wires with multimeter tests AC & DC, Resistance, Diode and Transistor hFE (0-1000). (Lohner, 2016).
Electrical Tape
Rope
Conductors
Several types of soil
Shewanella Bacteria

The MFC is composed of a soil-filled container populated by microorganisms. The soil was acquired from a local pond to mimic the circumstances of using a MFC in an emergency situation. The MFC has two compartments – the first with an anode and the second with a cathode - separated by a selectively-permeable membrane. The membrane allows for the flow of positively-charged ions.

Organic matter is oxidized by microorganisms which emit electrons. The electrons transmit via an electrical circuit to the cathode. Protons pass through the selectively-permeable membrane. The electrons and protons combine with oxygen to form water.

Anode: Anodic materials must be conductive, biocompatible, and chemically stable.

Cathodes: Water or Copper

Membrane

The MFC design requires the separation of the anode and the cathode compartments. In addition to conventional instruments used for chemical measurements in microbial systems, the MFC experiments required specialized electrochemical instrumentation for testing.

Experiments and Results

Date	Location	DCV (10)	ACV (10)	Electric Resistant (Ohms)	Observations
4/20/17	Garden	2.5	0	1k	Temp 80 degrees F, partly cloudy
12:10 pm					Ground was wet from previous rain
7:30 pm	Garden	2.5	1.8	1k	Temp 82 degrees F, cloudy
					Light rain
4/21/17	Garden	4	1.3	90	Temp 80 degrees F, sunny
2:00 pm					Ground was wet from previous rain
					Debris around site, bent

Beaker #1					
Date	**Location**	**DCV (10)**	**ACV (10)**	**OHMS (x10)**	**Observations**
3/21/17	Lab			3.9	Red on Cu
				4.5	Black on Zn
				7	Farther apart
					500 mL organic soil
4/10/17	Lab			0.5	Temp 69.5 degrees F
No water since 3/21/17; soil still moist					
					Added conductor produced max output
					Added DI water to 100 mL after reading
4/11/17	Lab	5	1.4		
4/13/17	Lab	3	1	1k	Moved Cu and Zn
					Added soil 100 mL - 500 mL
					No water added
4/17/17	Lab	3	1.2	1k	Reading higher without water
4/19/17	Lab	4	1.7	60	Temp 68.5 degrees F in room; colder weather
					500 mL soil, packed; visible separation between old and new
					Cu was moved deeper into the soil
					Put in 37 degree C incubator after reading
4/20/17	Lab	4	1.1	100	From 37 degree C incubator

Beaker #2	Location	DCV (10)	ACV (10)	OHMS (x10)	Observations
Date	Office	1	0.2	1k	No water since 3/21/17
4/19/17					Covered with bag
6:00 pm					Colder weather
					Added 45 mL of DI water and 10 mL of table sugar to 500 mL of organic soil; covered and placed in 37 degree C incubator
	Lab	2	0.9	1k	24 hours later
4/20/17					

Table 1: Electric Resistance (Ohms).

Conclusion

Bacterial extracellular electron transfer is a promising tool for converting chemical energy into electricity through microbial fuel cells, which combine hydrogen and oxygen to produce electricity. Microbial fuel cells are a promising new technology to generate power for emergency situations in a variety of locations around the world.

The MFC design requires additional work before prototyping can begin. Optimization of soil composition and improvements in MFC fabrication require additional studies. While these results are preliminary, this technology offers the potential for availability of an alternative electricity resource in resource-limited and emergency situations.

Acknowledgments

This research was supported by National Science Foundation and the American Association of Community Colleges through the 2017 Community College Innovation Challenge. We thank Frederick Community College for the opportunity to pursue this research. We also thank Pete Staveley for his contributions.

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