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ANALYSIS OF MICROBIAL FUEL CELL FOR ENERGY HARVESTING WITH WASTE WATER AND MOLASSES

ARUNGOVIND. M[1], PURUSHOTHAM. K.G[2], ARUNKUMAR. J[2] AND SENDILVELAN. S[1*]

*[*1]Department of Mechanical Engineering, Dr.M.G.R. Educational and Research Institute, University, Chennai- 600 095, India.*
[2]Department of Biotechnology, Dr.M.G.R. Educational and Research Institute, University, Chennai- 600 095, India.

ABSTRACT

Sustainable energy production from organic waste is gaining research interest. Microbial fuel cell (MFC) is a technology in conversion of waste water to useful energy. In this work an attempt has been made to analyze the performance of waste water on microbial fuel cell. The living cells in the anode chamber utilize substrate for the growth maintenance; as a result the electrons are supplied. The goal of the present work is microbial fuel design and its characteristics based on electricity generated using MFC. Various waste waters are used as substrate in MFC which create changes in rate of power generation and adaption of bacterial strains in various waste causing in variation in electron transfer and power output.

KEYWORDS: **Microbial Fuel Cell, Sustainable Energy, Waste Water Treatment, Bioenergy**

SENDILVELAN. S
Department of Mechanical Engineering, Dr.M.G.R. Educational and Research Institute, University, Chennai- 600 095, India.

***Corresponding author**

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INTRODUCTION

The microbial fuel cell is a new form of renewable energy technology that can generate electricity from what would otherwise be considered waste. Microbial fuel cell is a future technology capable of purifying different types of wastewater while converting chemical energy into electrical energy using bacterial as active biocatalyst. Traditional MFCs consist of two chambers in which electrodes are placed while a membrane separates the chambers from each other[1]. Micro-organisms in the anode chamber consume the substrate and produce electrons and protons. The produced electron is transferred by an external circuit to the cathode compartment and the generated protons are transferred by the proton exchange membrane to the cathode chamber[2]. Therefore, electrodes play a very important role in the efficiency of an MFC[3]. In fact, the electrons produced by bacteria are transferred on the anode's surface while on the cathode's surface an electrochemical reduction reaction takes place[4]. Hence, the surface of the electrodes is of significant importance in the overall performance of an MFC. More specifically, the higher electrode surface area leads to an enhanced MFC performance. Traditional electrode materials commonly used as anode and cathode include graphite, carbon cloth, and carbon paper[5]. The main advantage of MFCs is that they typically have long lifetimes, up to five years[6]. MFCs are capable to oxidize simple carbohydrates to carbon dioxide via biochemical reactions[7]. Recently, great attentions have been paid to MFCs due to their mild operating conditions and using variety of biodegradable substrates as fuel[8]. The performance of MFCs mainly depend on several important factors, such as system architecture, electrode material, electrode surface area, bacterial species, types of organic matter, operating conditions (solution conductivity, pH), and type of catholyte[9], a catholyte is the part of an electrolyte which is on the cathode side of an electrochemical cell that is effectively divided into two compartments. Single MFCs were used by many researchers for the purpose of power generation by means of pure and mixed cultures of active biocatalysts[10]. A series of attempts has been made to improve MFCs' performance using suitable substrates and microorganisms by application of process optimization[11].Many studies are underway with a focus on the fabrication of novel electrode materials in order to improve MFCs' system performance[12]. Progresses in nanotechnology and nanomaterial sciences have brought about evolutionary developments in the MFC technology. The materials at nano-scale exhibit different and unique properties in comparison with their macro-scale forms[13]. Various microorganisms are used in the anode chamber of MFCs including pure or mixed cultures[14]. A conventional MFC consisting of anode and cathode compartments which is separated by using a proton exchange membrane from each other. In the present study, a two-chamber MFC was inoculated by using a mixed culture, i.e., anaerobic sludge as biocatalyst in the anode chamber. All experiments were conducted in continuous mode. The uniformity of electricity generation at each individual MFC was investigated. The collective current and voltage production in MFC was also studied. Results of present research demonstrated that the novel fabricated stack was remarkably enhanced current and power at optimum conditions which can be used for low consumption electrical devices.

Microbial Fuel cell

Organic waste such as cow dung, sewage, food waste, industrial waste can be used as a substrate in microbial fuel cell. Anaerobic digestion is applied in MFC where organic matter gets digested by bacteria to produce useful electricity and treatment of waste water. It has been shown that the performance of a microbial fuel cell depends heavily on the primary substrate used in the process of fermentation. The metabolic process in the bacteria is very complex. It involves many enzymes. It may proceed by many different routes. It has been shown that a mixture of nutritional substrates can result even in higher extractable current than any single component[15]. The bacterial cell membrane functions as an energy transducing membrane operating according to the chemiosmotic principle. The translocation of protons towards the outside of the membrane results in the establishment of a proton electrochemical gradient. The pH gradient adds up to this membrane potential and results in the proton motive force. Keeping this theoretical background in mind let us now see how an MFC functions. A typical MFC as shown in schematic figure 1 consists of two compartments, one is the anodic and another is cathodic half-cells, which are separated by a selectively permeable, cation-specific membrane or a salt-bridge. The anodic chamber consists of microbes suspended under anaerobic conditions in the anolyte and the cathodic chamber contains the electron acceptor (oxygen). In essence, the electron donor is physically separated from the terminal electron acceptor across the two chambers. Das reported that the electrode reactions in a MFC compartments are as follows[16]:

Anodic reaction: $C_{12}H_{22}O_{11} + 13H_2O \rightarrow 12CO_2 + 48H^+ + 48e^-$

Cathodic reaction: $O_2 + 4H^+ \rightarrow 2H_2O$

Most of the electrons released from the process of oxidation are conveyed to the anode. Electron transfer to the anode can be accomplished by electron mediators or shuttling agents, directly by the cell or by means of nanowires. These electrons are directed to the cathode across an external circuit and for every electron conducted, a proton is transported across the membrane to the cathode for completing the reaction and sustaining the electric current.

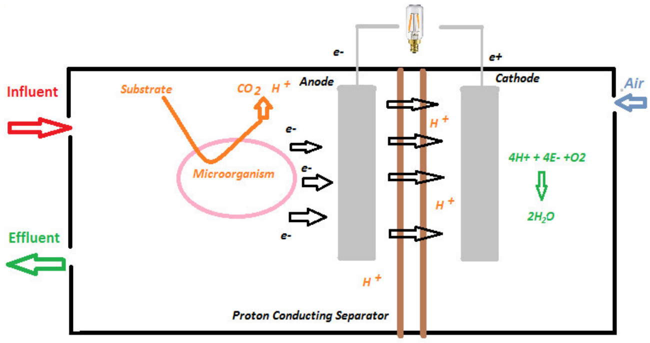

Figure 1
General Layout of a Two Chambered Microbial Fuel Cell

Microbial Fuel Cell Design
Experiments were conducted on a cylindrical microbial fuel cell, consisting of cylindrical shaped electrodes. Fuel cell chambers are separated by proton exchange membrane.

Table 1
Design Specifications

S.No	Parts	Size (mm)
1	Cylinder Diameter	110
2	Cylinder Length	120
3	Cylinder Thickness	5
4	End Plate Diameter	120
5	End Plate Thickness	6
6	Inlet Hole Diameter	14
7	Electrode Socket Diameter	3
8	Flange Outer Diameter	220
9	Flange Inner Diameter	80
10	Flange Fastener Hole Diameter	8

Electrodes are the conducting material which performs in transfer of electron from anode chamber to cathode chamber causing flow of electron. According to surface area and type of material performance of electrodes varies. Electrode selection plays important role in commercialization of MFC, carbon is one of a trusted material where it can be used as electrode effectively which is available in numerous forms of structure and surface area suitable in MFC. Carbon can be used in any type of MFC because of its flexibility in its size and shape[17]. Cost of carbon electrode is significantly cheaper for commercialisation. Carbon electrodes allow scans to more negative potentials than platinum or gold, as well as good anodic potential windows[18]. The most common form of carbon electrode is glassy carbon, which is relatively expensive and difficult to machine. Carbon paste electrodes are also useful in many applications. These electrodes are made from a paste of finely granulated carbon mixed with an oil substrate like Nujol. The paste is then packed into a cavity in an inert electrode body. Carbon paste electrodes have the disadvantage of being prone to mechanical damage during use. Here carbon cloths are used as an anode, as its surface area is high compared to other type of commercial carbon electrode. Steel mesh is used as a cathode as it has good conductive property and high surface area.

Figure 2
Carbon Cloth Electrode

Figure 3
Steel Mesh Cathode

Membrane is used to separate anode and cathode chamber where ion transfer takes place through this membrane this is also known as polymer electrolyte membrane (PEM), in this nafion membrane of material sulfonated tetrafluoroethylene based fluoropolymer-copolymer which are used in various fuel cell application. One of the most common and commercially available PEM materials is the fluoropolymer (PFSA) Nafion, a DuPont product. While Nafion is an ionomer with a perfluorinated backbone like Teflon, there are many other structural motifs used to make ionomers for proton exchange membranes. Many use polyaromatic polymers while others use partially fluorinated polymers. In this work also nafion was used as membrane in the microbial fuel cell developed as stationary fuel cell applications using bio waste as substrate.

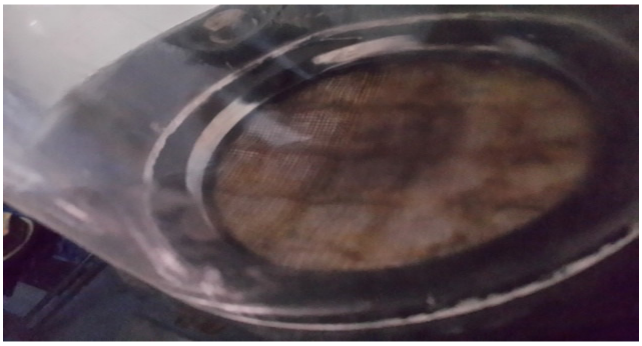

Figure 4
Proton Exchange Membrane

An anaerobic bacteria culture is a method used to grow anaerobes from a clinical specimen. Anaerobes are bacteria that can live only in the absence of oxygen which are used in microbial fuel cell in producing electric power by digesting waste organic substrate. An Effective Microorganism (EM) refers to any of the predominantly anaerobic organisms blended in commercial agricultural amendments or for environmental applications such as for septic tanks. EM technology is purported to support sustainable practices in farming, improve composting operations, and to reduce environmental pollution. An embedded based signal monitoring system using AVR controller is done by low-power Atmel 8-bit AVR RISC-based microcontroller combines 8KB of programmable flash memory, 1KB of SRAM, 512B EEPROM, and a 6 or 8 channel 10-bit A/D converter, implementing automatic control for a load by the current and voltage measuring continuously at an interval of every second, Desired value the control signal is pass buy the microcontroller to PC connected to it, which is loaded with visual basic software which collects and store data.

Methodology

Bio waste samples from different sources were used as a substrate and some samples with EM to make the mixture to have known bacterial culture for microbial fuel cell. This mixture was placed in a sealed chamber to avoid the oxygen, thus forcing the microorganism to use anaerobic respiration where microorganism in substrate digests organic matter aerobically. An electrode made of carbon cloth placed in the solution which was acting as the anode. In the second chamber of the MFC another solution was filled and placed another electrode. This electrode, called the cathode made of steel mesh which was positively charged and it was the equivalent of the oxygen sink at the end of the electron transport chain, these chamber were separated by a proton exchange membrane where ion transfer takes place. Connecting the two electrodes by a wire and completing the circuit.

Figure 6
Microbial Fuel Cell (MFC) Setup

Observation on Experiment
To start up the process rice washing water was used, the values of power output in mV was recorded by the data acquisition system. Biochemical activity of the microorganisms gradually increased electricity generation. At incubation time of 24 hours after inoculation, the output remained constant. The recorded voltage was 242,230, 210, 195,184, 145, 130 and 120 respectively for everyday for 8 days respectively for rice washing water with cow dung. The cathode and anode of MFC were connected together through a circuit to an external resistance (LED Bulb). The performance MFC with respect to time was monitored. Table 1 shows power output (in microvolt) on different sources of substrate.

Table 2
Power Output Analysis on Various Bio waste Substrates in Voltage (mV)

S.No	Substrate	24 Hrs	48 Hrs	60 Hrs	72 Hrs	84 Hrs	96 Hrs	108 Hrs	120 Hrs
1	Rice Washing Water (300 ml) with Cow Dung (100 ml)	242	230	210	195	184	145	130	120
2	Rice Washing Water (300 ml) with Molasses (100 ml)	251	237	222	205	193	154	136	128
3	Industrial Coolant Waste (300 ml) with Cow Dung (100 ml)	232	224	210	198	175	156	130	127
4	Industrial Coolant Waste (300 ml) with Molasses (100 ml)	224	236	221	200	185	137	128	120

RESULTS AND DISCUSSION

Due to the presence of resistance, the power and voltage considered as operational electricity as shown in figures.

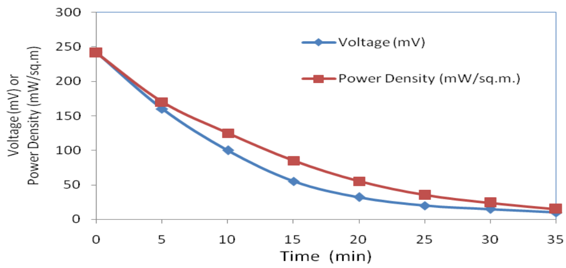

Figure 7
Voltage or Power Density with Time for Substrate Rice Washing Water (300 ml) with Cow Dung (100 ml)
The Voltage as well as the power density decreases with time. Upto 30 minutes the LED is bulb is working effectively in this experimental runs.

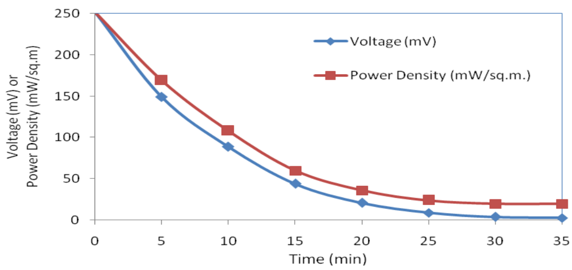

Figure 8
Voltage or Power Density with Time for Substrate Rice Washing Water (300 ml) with Molasses (100 ml)

It has been found that a mixture of bio wastes with Effective microbes can result in higher extractable current than single medium. Industrial waste such as coolant waste can be treated using microbial fuel cell along with power generation. Maximum output of 251 microvolt is achieved with molasses with Effective microbes. Ph value of substrates during process is found to be 4.

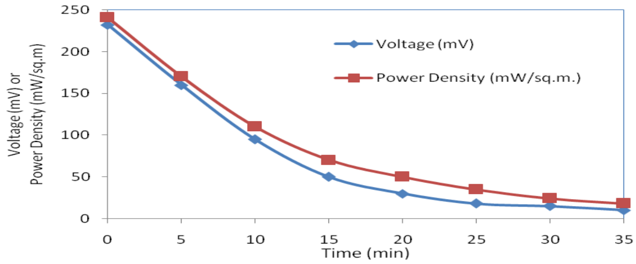

Figure 9
Voltage or Power Density with Time for Substrate Rice Washing Water (300 ml) with Cow Dung (100 ml)

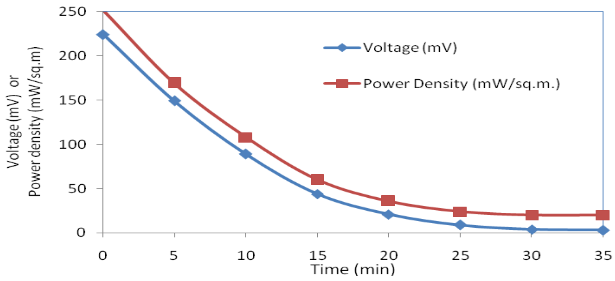

Figure 10
Voltage or Power Density with Time for Substrate Rice Washing Water (300 ml) with Molasses (100 ml)

CONCLUSION

From this analysis, it has been conclude that substrate from various sources such as cattle waste, molasses, rice washing water, and industrial coolant effluent, individually and also in combinations can be used in MFC cells to generate electricity. MFC is an effective way of generating electricity and also clean the waste water. As a demonstration, one LED bulb and used the fabricated stacked MFC as power source and the device were successfully operated for the duration of 30 minutes per days. However, this technology is only in research stage and more research is required before domestic MFCs can be made available for commercialization.

CONFLICT OF INTEREST

Conflict of interest declared none.

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