Electricity Production Potential of Microbial Fuel Cell from Sewage Sludge

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Abstract: ***The microbial fuel cell (MFC) technology has captured the attention of the scientific community for the possibility of transforming organic waste directly into electricity through microbial catalyzed anodic and microbial/enzymatic/abiotic cathode electrochemical reactions. The construction and analysis of MFCs requires knowledge of different scientific and engineering fields, ranging from microbiology and electrochemistry to materials and environmental engineering. A two - chambered microbial fuel cell (MFC) was constructed. There are two chambers, the anode and cathode chamber. The formal contains the sewage sludge while the later contains water, then a salt bridge connects the two chambers (half cells) to form a complete circuit, hence electricity would be harvested. The anode chamber supplied with some specific bacteria like Shewanella oneidensis which feeds on the decomposed matter and reduces metals to release positively charged ion, while the cathode chamber when aerated properly produces negatively charged ion, then the semi - permeable membrane complete the circuit by acting as the salt bridge. These positive and negatively charged ions were then harvested using copper wires and tested to reveal the presence of electrical current, while it was also able to clean sewage water. Current generated in volts from the cells on day one were higher (0.16 – 0.12 volts) but decline as the day's progresses (0.10 - 0.13 volt). Microbial Fuel Cell (MFC) A2 was able to generate 0.21 Volts when agitated which is greater than its initial output of 0.15 Volts while MFCs A2 generated 0.16 Volts when aerated which is greater than its initial output of 0.12. This form of electric power generation is renewable, cheap, environmental friendly, that if properly harnessed would supplement the already available hydro and solar electricity to provide the teeming growing population adequate power supply for industrialization and innovations.***

Keywords: Microbial Fuel Cell, Sewage Sludge and Electricity

1. Introduction

Energy needs around the world are rising at a pace yet unmatched by sustainable energy sources (Lal Deeksha, 2013). In the recent decades, consumption of energy within the world has had a prosperous trend (Rahimnejad, *et al.*, 2015). Energy sources are classified into three batches: fossil fuels, renewable sources and nuclear sources (Ayhan Demirbas, 2006*)*. Fossil fuels negatively influence the nature owing to the emission of carbon dioxide. It follows logically from what has been said that the consumption of fossil fuels has severely imperilled human life through its drastic aftermaths, such as global warming and atmospheric pollution (Rahimnejad, *et al.*, 2012). For thousands of years we have relied on burning fossil fuels to generate energy, but in today's world using oil, gas and coal for our energy needs is becoming a problem because of its effects on climate change (Skjaerseth, *et al*., 2001). Climate change is one of the greatest environmental challenges that we are and have ever faced, and the main cause behind it is our dependence on petroleum and other fossil fuels is the primary means by which we produce electricity, but it also leads to heavy concentrations of pollutants in our soil, air and water. (Irena, *et al.*, 2006). All sorts of ideas and inventions for developing greener and more efficient methods of energy generation are increasingly being hailed across the globe; one of such approaches with a tremendous potential is the use of microbes for the production of electricity. The first report that bacteria can generate electricity appeared more than a hundred years ago, The original idea of utilizing microbes to generate electricity was conceived and attributed to Potter (1911). However, his work did not gain any major coverage at that time. It is only in recent years that this ability of microbes has been rediscovered (Bennetto, 1990). Bio - fuels, in general are expected to reduce the dependence of petroleum and other fossil fuel with associated political and economic vulnerabilities, reduce greenhouse gas emissions and other pollutants, and revitalize the economy by satisfying the increasing the demand for energy. (Balat & Balat 2009). Enormous quantities of Agro - industrial waste residues are generated throughout the world from processing raw agricultural materials for foods and other industrial activities. (Nigam, & Pandey, 2009). These waste and their disposal have become an environmental concern especially when they are non bio - degradable. Energy efficiency will improve faster than global economic growth due to the rapid electrification of the world's energy system, leading to a plateau in energy demand from 2030 (Energy Transition Outlook, 2017). Microbial fuel cells have the property of consuming almost any type of organic waste, and generating energy at the same time. Most of the substrates whichinclude sugar and starch are readily available, easy to store. (Rabaey, *et al.*, 2005). This twin set of extraordinary uses, if perfected, will resolve the energy crisis and waste disposal problems that the world currently faces. Microbial fuel cell has many distinct advantages over the conventional fuel cells. For one, they have higher efficiency, and produce little pollution. Some MFCs can even produce hydrogen along with electricity, conveniently solving the hydrogen problem as well, in a process called electrohydrogenesis (Logan, *et al.*, 2006). The reason for this renewed interest, is the need for new resources of energy and better understanding of the microbial system in relation to the electron transport and eventually, the development of Microbial Fuel Cells thus, a Microbial Fuel Cell (MFC) capable of generating electricity directly from a large variety of organic or inorganic compounds, using a microbe as a catalyst (Marcus, *et al.*, 2007). Conventionally, fuel cells convert chemical energy to electrical energy, by consumption of a fuel at the anode and an oxidant at the cathode (Rabaey, *et al.*, 2005). *Shewanella oneidensis* is an important species of marine bacteria (Zhao, *et al.*, 2010) that can transfer electricity into metals and minerals and their interaction depends on special proteins on the surface of the bacteria (Franks &Nevin, 2010*)*. This bacterium is able to transfer electrons to metals and is a key agent in biogeochemical metal cycling, subsurface bioremediation, and corrosion processes (Marsili e*t al.*, 2008). More recently, these bacteria have gained attention for its ability to transfer electrons from the cell surface to conductive materials and be used in multiple applications *(*Marsili *et al.*, 2008). Thus, this study aims to establish efficient microbial fuel cell, harvest electricity directly from sewage sludge and treat sewage water using the same technique.

2. Materials and Methods

Microbial fuel cell layout plan: With some sludge, salt bridge and water, a closed circuit that would generate current was created according to the methods of Rahimnejad *et al.* (2012).

MFC Design: A prototype of the MFC was first designed using free hand sketch. This basic design was then constructed as a working model in the laboratory.

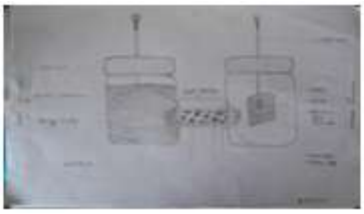

Plate 1: Freehand Sketch of MFC Prototype for Construction

Building a small scale MFC: The method of Logan, (2010) was used in building the H - type or the dual chamber MFC set up. This would facilitate more accurate inputs in the anode and cathode chambers due to the fixed volume of the chambers. This set - up will enable the use of other inoculum instead of just air in the cathode chamber.

Collection of sludge sample: Sewage samples were collected using a spade to harvest benthic sediments (zone for electrochemically active anaerobic bacteria like *Shewanella onediensis*) in drainage line leading to the Otamiri also known as School River within the axes of Federal University of Technology, Owerri.

The salt bridge: Half cup of salt was added to water and allowed to boil. While boiling, 1cm to 5 cm cotton fibre ropes was immersed in the solution. The salt solution was left to boil to dryness and was then allowed to cool. After cooling, the cotton fibre was firmly wrapped with nylon and black tape. The purpose of a salt bridge is to maintain charge balance between the two chambers as the electrons would be moving from one - half cell to the other.

The anode and cathode chambers: Permanent marker was used to outline position creating of holes, 6 cm away from the lid on one side of the plastic containers; anode chamber and cathode chamber. The hole which is 2 cm in diameter was large enough and fit the salt bridge appropriately. Lids of the containers were drilled at the centre to make a small hole for the copper wire. Optional hole was also created on the container that would serve as the anode chamber for the placement of an air pump. The salt bridge was placed into the side holes on the container and glue into place. These were done with gloves to avoid irritation of the skin.

Preparation of the electrode: Each end of the red and black copper wires was stripped off with a wire stripper and one end was folded around an aluminium mesh and through the pre - drilled holes on the containers and glued.

Assembling the bio - fuel cell: Salt Bridges were ensured to fit - in, appropriately into holes on both the anode and cathode chambers. Air pumps were inserted through pre - drilled holes on the cathode chamber and were sealed with glue. Each end of the salt bridge passed through pipe connectors and was tighten until it is securely in place. The anode chambers were filled with sludge with constant removal of air bubbles and the electrodes were inserted to make the anode. While the cathode chambers were filled with distilled water and half cup of salt was added and stirred, for homogeneity. The second electrodes were also placed through the drilled holes on the lids and were sealed. Alligator clips were connected to the protruding copper wires and the aquarium pump was turned on to aerate the cathode solution occasionally.

Optimizing the MFC design: Microbial fuel cells constitutes of electrodes (anode and cathode) chamber and salt bridge. The Anode chamber is an anaerobic chamber that contains the substrate and the biocatalyst microorganism (*Shewanella onediensis*). The cathode chamber was maintained aerobically with catholyte in it, while the salt bridge between cathode and anode chamber facilitates the transfer of ions (protons).

MFC Operation: substrates were added to the anode chambers and were completely sealed to maintain anaerobic condition. The reactor was sprayed with CO^2 before sealing completely to ensure complete removal of oxygen. A batch configuration was employed and readings were taken for a period of 2 weeks. The rise and decline in readings was recorded for this period and readings were taken every 2days. On the days scheduled for taking readings, the samples were also agitated and aerated and readings noted.

Physio - chemical test: A physio- chemical analysis which includes test for odour, colour and pH were done using the supernatant produced by the sewage sludge.

Measurement of output: The performance of the biofuel cell was evaluated by determining its voltage output using multimeter. The multimeter was turned on and the voltages were measured between the anode and cathode. Resistors were also connected biofuel cells to determine its performance using its power output. The output (current) of the MFC is expressed in milli - ampere (mA). The multimeters were also used to measure Open Circuit Voltage (OCV) and Ohm's Law was use to calculate Power (P) and hence the power densities were also calculated. The formulas used includes **V=IR, P=VI, PD= VI/A**

Where;

- V - Volts (V)
- I – Current (mA)
- P - Power (mW)
- PD - Power Density (mW/m^2) x Surface Area of electrode (m^2)

Data analysis: Comparisons were made by varying electrode types and materials to establish best design. Readings from the multimeter were recorded only after steady and constant values were obtained. The multimeters were connected in series with MFC when measuring current and was connected in parallel while measuring OCV. A graph was generated (Current Vs Time) to visually represent the comparison at the end of the experiment.

3. Results

Volts output from the microbial fuel cell presented in Table 1. Reveal that the MFCs generated current using sewage sludge, although were in small amount of about 0.12 volts and 0.16 volts

Table 1: Microbial Fuel Cell Volts Output

	Microbial fuel cells														
Output in Volts	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	C5
	0.12	0.15	0.13	0.13	0.14	0.15	0.12	0.12	0.14	0.15	0.14	0.13	0.13	0.16	0.13
Total	0.67					0.68					0.68				

Figure 1: shows continuity in current production by the MFCs monitored for days. Current generated in volts from the cells on day one were higher (0.16 – 0.12 volts) but decline as the day's progresses (0.10 - 0.13 volt).

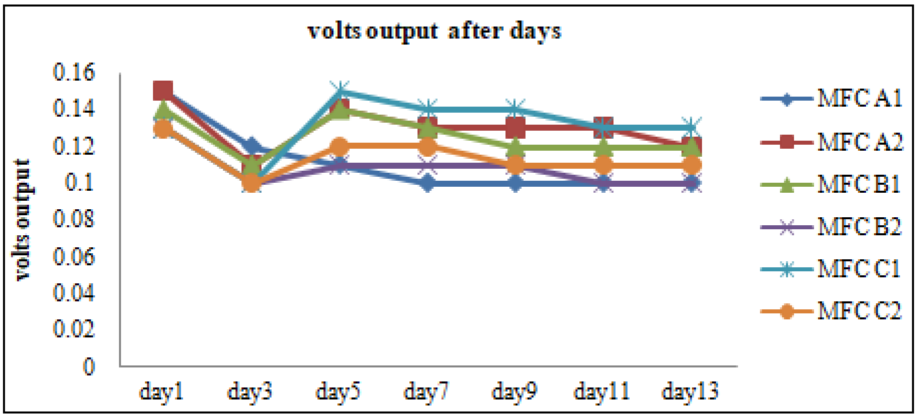

Figure 1: Average Volts Output Generated After Days (VOPAD) in the Microbial Fuel Cells

Microbial Fuel Cell (MFC) A2 was able to generate 0.21Volts when agitated which is greater than its initial output of 0.15 Volts, while MFC A1 was able to generate 0.16 Volts when agitated which is greater than its initial output of 0.12 Volts. MFC B1 was able to generate 0.20 Volts when agitated which is greater than its initial output of 0.15Volts, while MFC B2 was able to generate 0.16Volts when agitated which is greater than its initial output of 0.12Volts. MFC C1 was able to generate 0.20 Volts when agitated which is greater than its initial output of 0.16 Volts, while MFC C3 was able to generate 0.18 Volts when agitated which is greater than its initial output of0.13 Volts. Stability were achieved in MF cell A (day 7 and day 11), B (day 5 and day 7) and C as shown in figure 2 - 3 below.

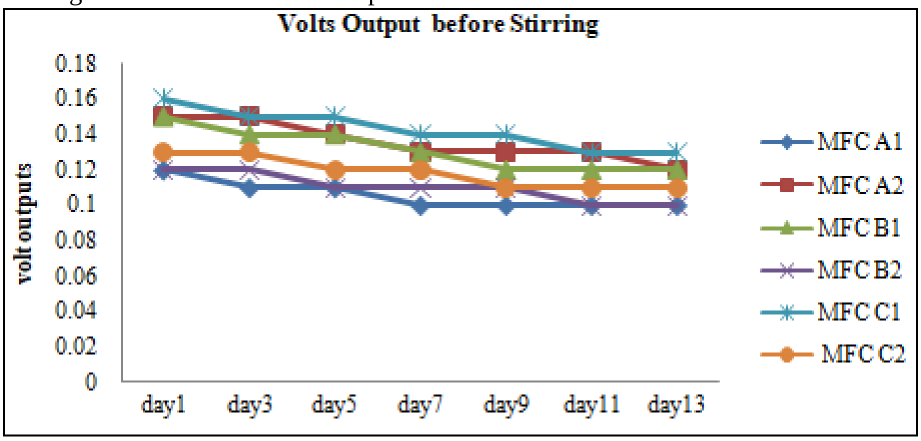

Figure 2: Volt Output before Stirring the Microbial Fuel Cells

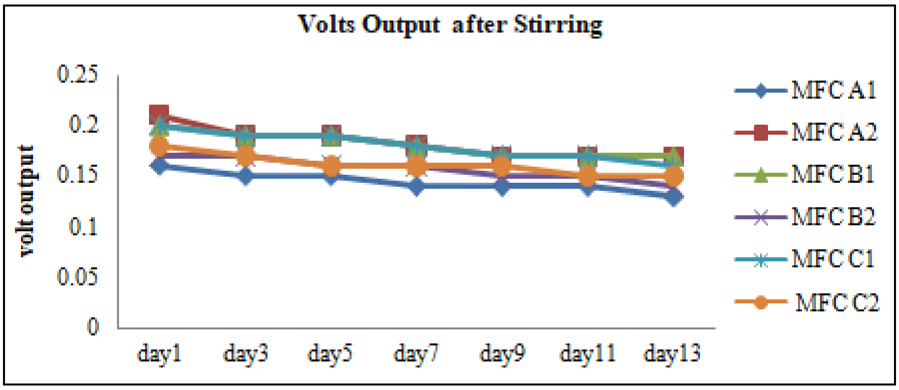

Figure 3: Volts Output After Stirring the Microbial Fuel Cells

Aerating cathode chambers were observed to increases electrical output as shown in Figure 4 - 5. MFCs A1 generated 0.19 Volts when aerated which is greater than its initial output of 0.15 Volts while MFCs A2 generated 0.16Volts when aerated which is greater than its initial output of 0.12Volts similar results were obtained for other MFCs.

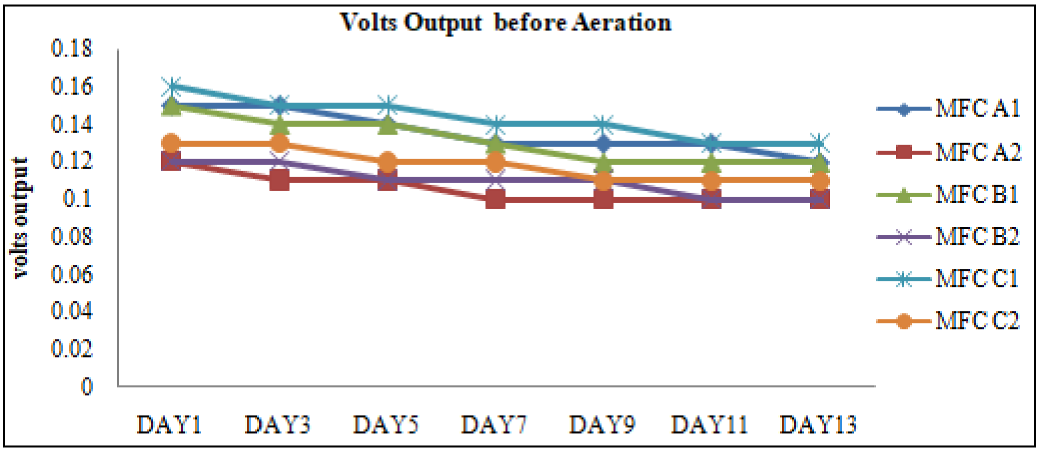

Figure 4: Electricity Output in Volts/Day on MFCs before aerating

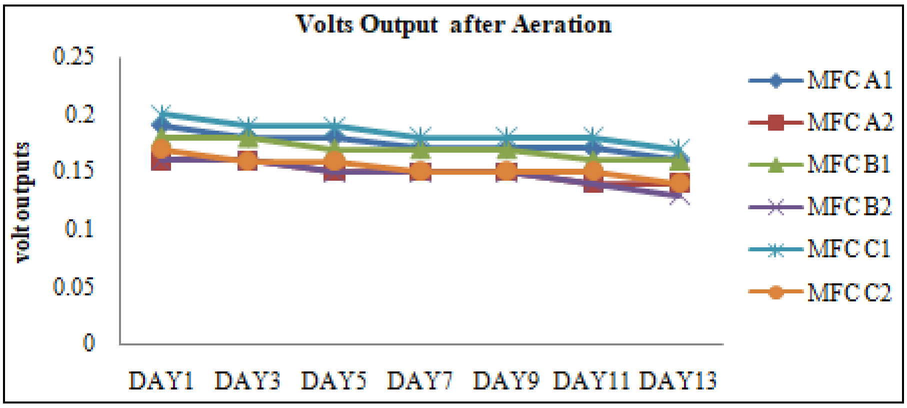

Figure 5: Electricity Output in Volts/Day on MFCS after Aerating

4. Discussion

Energy in general are classified into three main sources which are, the fossil fuel, the nuclear sources, and the renewable sources (Akdeniz, *et al.*, 2002). From this study, The Sewage sludge were used to generate electricity by setting up a microbial fuel cell which a source of renewable energy that would play vital role in supplementing the continuous electricity demand by the teeming increasing population of the world for domestic use, innovation, development, industrialization, recreational purposes and agriculture. Energy generation using microbial fuel cells are beneficial in reduction of toxins cause by sewage water.

From the results, the rapid depreciation of currents after the first day would be as a result of isolation of sewage sludge from its natural environment, hence there is reduction in supply of nutrients, however the organisms involved in electricity generation adapts to the new environment. Microbial Fuel Cell (MFC) A2 was able to generate 0.21 Volts when agitated which is greater than its initial output of 0.15 Volts, while MFC A1 was able to generate 0.16 Volts when agitated which is greater than its initial output of 0.12

Volts. This is also similar to Logan (2008) report that bacteria oxidize organic matter and in the process release electrons. In anodic chamber, oxidation of substrate in the absence of oxygen by respiratory bacteria produce electron and proton that are passed onto terminal e–acceptor. However, in absence of e - acceptor in a MFC, some microorganisms pass electron onto anode (Wrighton & Coates, 2009). The increase in the electrical output after stirring suggests metabolic reactions and activities of the cells, enhancing homogeneity of the nutrients in the sludge. Aeration of the cathode chamber increase availability of oxygen in the chamber, thus increasing reaction rate in the cell. this also support Alzate - Gaviria (2011), report that supply of air or other inoculum at cathode is essential to provide dissolved oxygen for the reaction of electrons through an external circuit, protons while oxygen at the cathode, completes the circuit and produce power.

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