Evaluation Of Electricity Generation From Animal Based Wastes In A Microbial Fuel Cell

Duduyemi Oladejo, O.O. Shoewu, A.A. Yussouff, Hunyibo Rapheal

ABSTRACT: Electric current from organic waste of poultry droppings were generated with A Microbial Fuel Cell (MFC) technology to evaluate affects of temperature (30 to 50°C), 100g/l, 300g/l and 500g/l slurry concentrations prepared with the distilled water and inoculated when introduced into the anodic chamber. A constant concentration of 50g/l of the oxidizing agent (Potassium ferricyanide) at the cathode chamber was prepared to evaluate the voltage and current generated by the set up for 7 days in each case. Higher slurry concentrations were observed to generate higher initial current and voltage than in lower concentrations. Higher slurry concentrations also demonstrated sustained power generation up to the day 6 before decline. A maximum current of 1.1V and 0.15 mA was achieved while the temperature variation was observed to have minimal effect within the range considered at low concentration. A (MFC) is a biochemical-catalyzed system, capable of generating electricity as a by-product, also providing an alternative method of waste treatment. **Application:** Alternative power source and waste treatment.

Keywords: Anode, Cathode, Electrons, Energy, Organic, Microbial, Salt-bridge

1. INTRODUCTION

Power generated using biomass-based renewable energy technologies is a promising option in limiting the country's dependence on fossil energy for power generation. Renewable Energy Master Plan (REMP, 2007) foresees increasing the country's electrification demand to a total of 14,000 MW by 2015 of which RE will constitute about 701 MW (5%). It is envisaged that, by 2025, the total electricity demand will have increased to about 29,000 MW, with RE constituting up to 10 % of the country's overall energy demand. The plan targets contributions to the electricity supply mix from biomass sources to around 50 MW for the year 2015 and 400 MW for 2025 [1]. The most important part of this option is on-site power generation via mini-grid systems [2]. The microbial fuel cell (MFC) is a new form of renewable energy technology that can generate electricity from what would otherwise be considered waste. Microbial fuel cells (MFCs) are devices that use bacteria as the catalysts to oxidize organic and inorganic matter and generate current using wastewater indicate that MFCs can remove organic matter to a comparable extent that which is achieved by current wastewater treatment plants. Fuel cells are a novel addition to the inventory of alternate energy sources having minimal or no net-CO2 emission. Economic growth in Nigeria is being seriously affected by the lack of a stable source of power. Nigeria's electricity consumption per capita is approximately 7% and 3% respectively with about half of Nigerian households not being connected to the national grid, self-generation (diesel or petrol generators) in Nigeria is estimated at 6000 MW, and it is estimated that about N80 (€0.36)/kWh is spent burning kerosene and candles [3].

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Since the turn of the 21st century MFCs have started to find a commercial use in the treatment of wastewater [4]. Developing new method of energy using renewable and carbon-neutral sources has opened up a new approach to energy supply. Power generation through the utilization of biomass has proved to be a possible path in achieving economic, social and environmental sustainability in the country. Unlike a battery, a fuel cell does not store energy. Instead, it converts energy from one form to another (much like an engine) and will continue to operate as long as fuel is fed to it. A MFC uses bacteria to catalyze the conversion of organic matter into electricity by transferring electrons to a developed circuit [5]. Cell growth was inhibited substantially when these microbial fuel cells were making current, and more oxidized end products were formed under these conditions and that sludge production can be decreased while electricity is produced in fuel cells [6]. Fuel cells that use bacteria are classified as two different types: biofuel cells that generate electricity from the addition of artificial electron shuttles (mediators) and microbial fuel cells (MFCs) that do not require the addition of mediator. The first step requires the removal of electrons from some source of organic matter (oxidation), and the second step consists of giving those electrons to something that will accept them (reduction), such as oxygen or nitrate. This technology can use bacterium already present in wastewater as catalysts to generating electricity while simultaneously treating wastewater [7]. Single chamber MFCs treat roughly 50 to 70% of the chemical oxygen demand (COD) present in wastewater in a 12 hour time span [8]. Unlike conventional fuel cells, MFCs have certain advantages like high energy-conversion efficiency and mild reaction conditions.[3] In addition to microorganisms that can transfer electrons to the anode, the presence of other organisms appears to benefit MFC performance. It is reported that, a mixed culture generated a current that was six fold higher that that generated by a pure culture [9]. If certain bacteria are grown under anaerobic conditions (without the presence of oxygen), they can transfer electrons to a carbon electrode (anode) The electrons then move across a wire under a load (resistor) to the cathode where they combine with protons and oxygen to form water. When these electrons flow from the anode to the cathode, they generate the current and voltage to make electricity. Among the electrochemically active bacteria are, *Shewanella putrefaciens*, [10] and *Aeromonas hydrophila* [11] and others. Mediator-less MFCs are a more recent area of research and, due to this, factors that affect optimum efficiency, such as the strain of bacteria used in the system, type of ion-exchange membrane, and system conditions (temperature, pH, etc.) are not particularly well understood. [12] From biochemical concepts, microbes derive nutrition for their sustenance? Chemotrophic microbes utilize organic and other biodegradable compounds, under diverse conditions. The electrons resulting from the oxidation are conveyed to an electron transport chain, across appropriate electron carriers depending on the terminal electron acceptor molecule. In aerobic organisms, this terminal acceptor is oxygen which takes up the electrons and gets reduced to water. [13]. The chemiosmotic hypothesis states that electron transfer chains of bacteria are coupled to the translocation of protons across the membranes which are in turn linked to ATP synthesis by the proton electrochemical potential across the energy transducing membrane [14]. Examples of substrate for MFC's include human, animal, and industrial wastewater, along with sugars, starch, and cellulose [15]. However, the use of Poultry waste has not been reported and they are readily available in all poultry farms. In this study the effects of substrate concentration, temperature and time was studied on the magnitude of voltage and current generated and their respective optimised values using poultry droppings. The objective of this research is aimed at studying factors affecting the production of electricity from poultry waste and evaluating their effects in power generation. These factors of interest include temperature, concentration and time.

2.0 MATERIALS AND METHODS

2.1 Materials

Poultry droppings from a local commercial farm in Epe surburb town of Lagos were obtained, dried and pulverised. A mesh of about 0.05cm was used to sieve the samples to obtain relatively uniform size materials. solution or slurry of relative homogeneity.A typical microbial fuel cell (MFC) was constructed, consisting of two separate chambers, one of these an anaerobic anode chamber and the other an aerobic cathode chamber. Both were connected via a salt bridge embedded with Potasium Ferricyanide in replacement to Proton Exchange Membrane (PEM) such as Nafion or artificial electron shuttles -mediators [16]. In each chamber was embedded graphite electrode connected to wire with alligator clips and kept air tight with epoxy sealant. The wires were loaded over a multi-meter for effective evaluation of the current and potential differences. The salt bridge was prepared with water solution containing concentrations of 3% NaCl and 1.6% agar was allowed to boil inside a microwave oven for nearly 3 minutes. The hot solution was poured into sawed PVC pipe sections each of length 25 cm long by sealing one end with polythene. The setup was thereafter allowed to cool for nearly 2 hours and fixed into the set up [15]. One chamber generates electricity from the addition of biodegradable organic matter from a poultry farm. Potassium ferricyanide was utilized as the oxidizing agent. Potassium ferricyanide was added to the cathode to accept electrons. It is very reactive with the graphite electrode. Ferricyanide has a fairly positive potential compared to the organic matter in the anode and helps to drive the flow of electrons. A pictorial view of the set-up is shown in Plate 1 and schematically presented in Figure1. The electrons move across the salt bridge to the cathode where they combine with protons, and oxygen to form water.

2.2 Methods

Known weights of the poultry dropping (samples) were measured in different set up consisting of 100g/l, 300g/l and 500g/l slurry concentrations prepared with the distilled water and inoculated when introduced into the anodic chamber. A constant concentration of 50g/l of the oxidizing agent (Potassium ferricyanide) at the cathode chamber was prepared and connected to the anodic chamber via the salt bridge. The temperature of the media was controlled in a steam bath at different temperatures varied between 30^{o}C and 50^{o}C. For every sample, the voltage and current generated by the medium were measured and recorded for a period of seven days and the effects of the temperature and concentration variations were studied. A further study on the interactive effects of the variables was investigated by the application of the Response surface methodology of Design Expert 6.0 (2007) software package. The summary of the design is shown in Table 1 using the boundary conditions to generate the 18 set of experiments which were replicated. The respective Voltages and Current generated were measured and recorded as presented in Table 2 in coded terms.

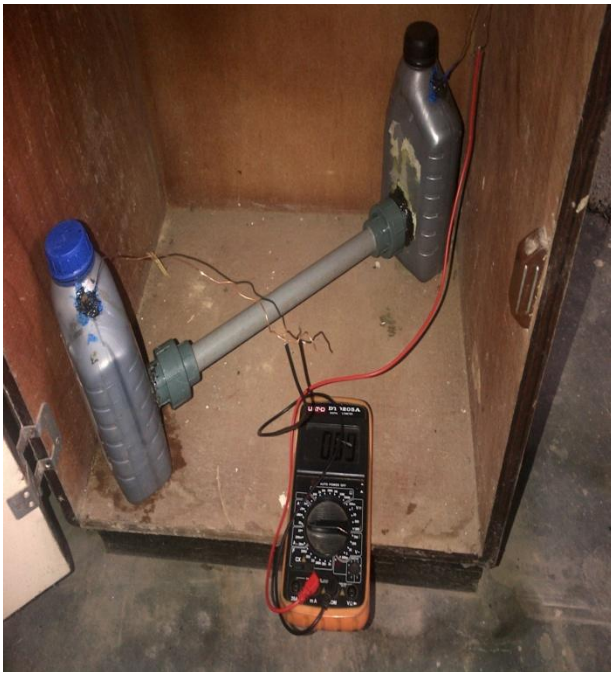

Plate 1: *Pictorial set-up of a microbial fuel cell*

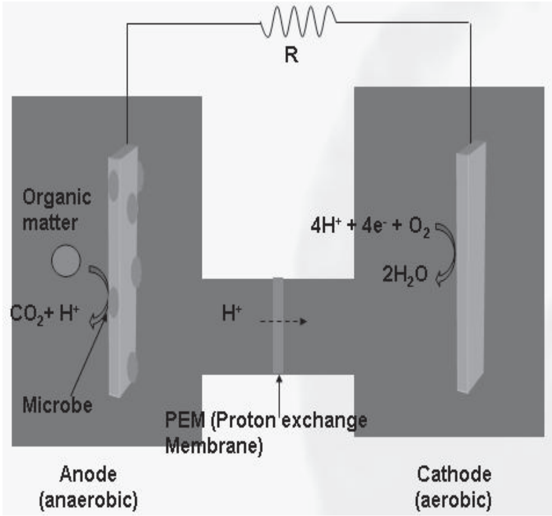

Figure 1. *Microbes remove the electrons from organic matter and transfer them to the anode in the anaerobic chamber. (-courtesy of Jung Rae Kim)*

Table 1: *Design Summary of Experiment*

Factor	Name	Units	Type	Low Actual	High Actual	Low Coded	High Coded
A	Conc	g/L	Numeric	100.0	500.0	-1.000	1.000
B	Temp	DegC	Numeric	30.00	50.00	-1.000	1.000
C	Time	Day	Numeric	1.000	7.000	-1.000	1.000

Table 2: *Results of Voltage and Current generated from Microbial Fuel Cell*

Run	Factor1 A:Conc g/L	Factor 2 B:Temp Deg C	Factor 3 C:Time Day	Response 1 Voltage Volts	Response 2 Current Amps
1	1.000	-1.000	-1.000	0.8230	0.0700
2	0.0000	-1.000	1.000	0.6170	0.0400
3	1.000	1.000	1.000	0.9680	0.1100
4	-1.000	-1.000	1.000	0.5470	0.0200
5	1.000	-1.000	1.000	0.9630	0.1100
6	1.000	0.0000	-1.000	0.8610	0.0900
7	1.000	1.000	-1.000	0.8690	0.0900
8	-1.000	-1.000	-1.000	0.3650	0.0200
9	0.0000	0.0000	0.0000	0.8910	0.1200
10	1.000	-1.000	-1.000	0.8230	0.0700
11	-1.000	-1.000	-1.000	0.3650	0.0200
12	-1.000	1.000	-1.000	0.3980	0.0500
13	-1.000	0.0000	1.000	0.5720	0.0200
14	1.000	-1.000	0.0000	1.0020	0.1300
15	-1.000	1.000	0.0000	0.5560	0.0500
16	0.0000	0.0000	0.0000	0.8910	0.1200
17	1.000	1.000	1.000	0.9680	0.1100
18	10.0000	1.000	-1.000	0.6310	0.0800

3. RESULTS AND DISCUSSION

The concentration of samples subjected to different temperatures generated voltages that followed same pattern. In 100g/l samples, temperature did not seems to affect the respective increase in voltage at different levels of temperatures up to the day 5 as observed in Figure 1a. On the other hand, the current recorded was found to follow a sinusoidal wave pattern which decreased drastically after day 4 Figure 1b. The effect of temperature at higher substrate concentration of 500g/l was plotted in Figures 2a and 2b for the voltage and current generated respectively.

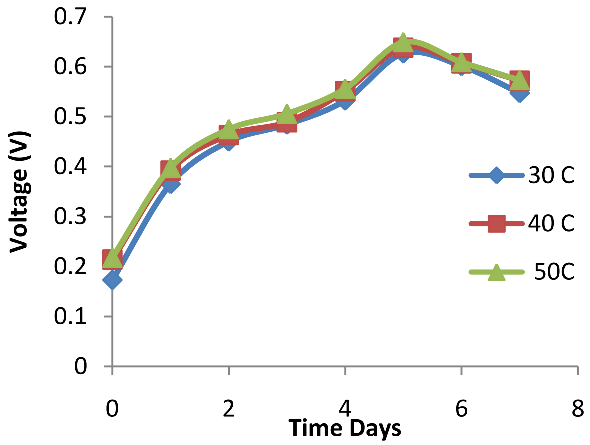

Fig. 1a: *Effects of Temperature variation on the Voltage output in the MFC 100g/L*

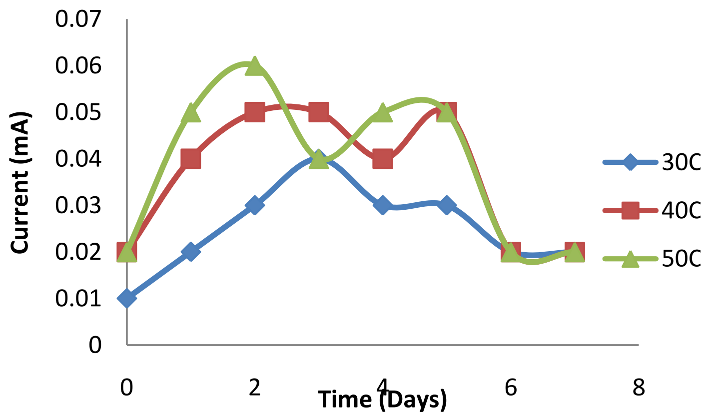

Fig.1b: *Effects of Temperature variation on the Current output in the MFC in 100g/L.*

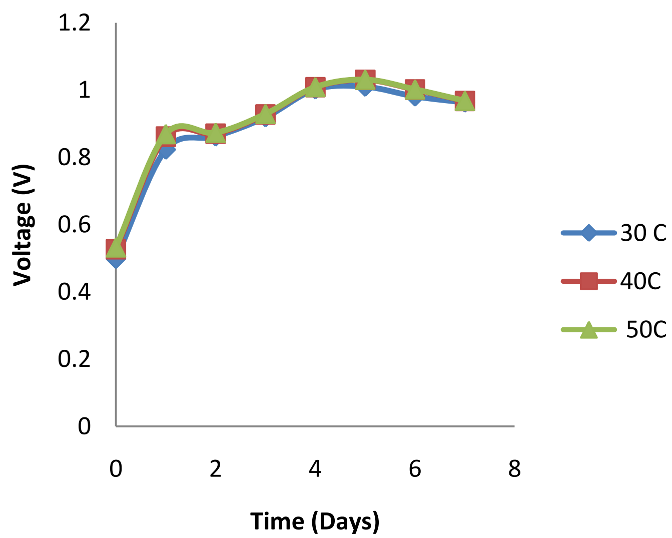

Fig. 2a: *Effects of temperature on voltage in high substrate concentrations 500g/L.*

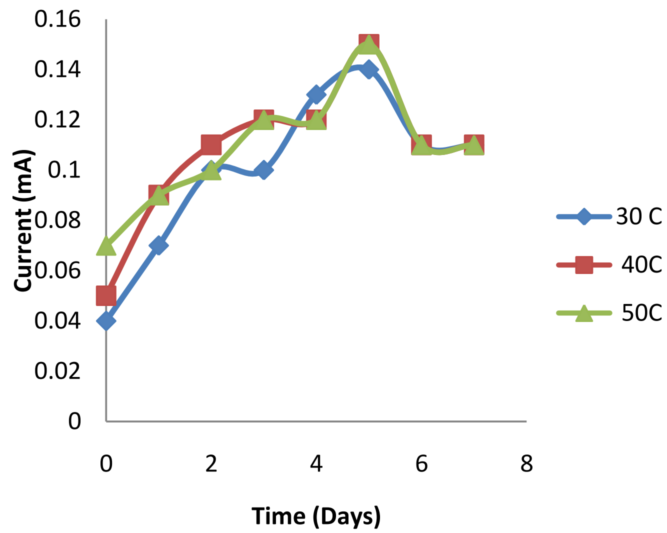

Fig. 2b: *Effects of temperature on current in high substrate concentrations 500g/L.*

The trends in Figures 1a and 2a were similar for voltage output irrespective of the temperature. However, this trend was different for current as temperature influenced the output up to day 4. This may be consequential to the depletion of substrate with time. The potential difference curve started from different initial steep of 0.2 mA and 0.5mA and increased steadily to about 1.1 mA and was temporarily sustained up to day 7 in 500g/l. Samples in higher temperature environment produced higher effects in both cases as the resistance of the flow of the electrons is minimised at high temperature. In many MFCs the ohms law defines the relationship between the voltage and current characteristics of an electrical conductor. The ohmic resistance plays a dominant role in defining the point of the maximum attainable voltage and current in the MFC. This is in conformity with the submission that Coulombic efficiencies and overall energy recovery varied as a function of operating conditions and that anaerobic digestion, are adversely affected by temperatures below 30 °C. [17]. The magnitude of the substrate concentration was also investigated on the voltage and current generation in the MFC. The current was found to be sustained up to day 7 in all the samples, and the voltage output in 300g/l sample was higher than in other lower sample concentrations Figure 3a. The same trends were also observed as 300g/l samples recorded the highest amperage (Figure 3b). This may be attributed to availability of substrate with time which also is dependent on the growth phase and microbial population in depleting the substrate anaerobically and subsequent decline in current and voltage generated. Some of the factors that are most salient to depletion of energy generation in the MFC include both the resistance to the flow of electrons through the electrodes and interconnections, and flow of ions through the salt bridge. Concentration losses (or concentration polarization) also occur when the rate of mass transport of a species to or from the electrode limits of the current recorded. Concentration losses occur mainly at high current densities due to limited mass transfer of chemical species by diffusion to the electrode surfaces as well as to the anodic and cathodic electrolytes.

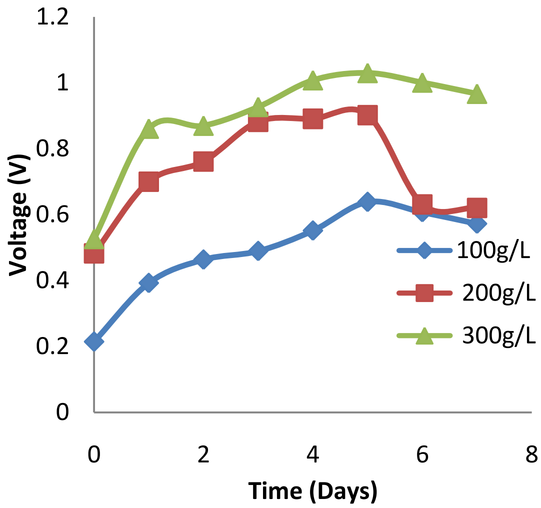

Figure 3a: *Effects of the substrate concentration on voltage generated in the MFC*

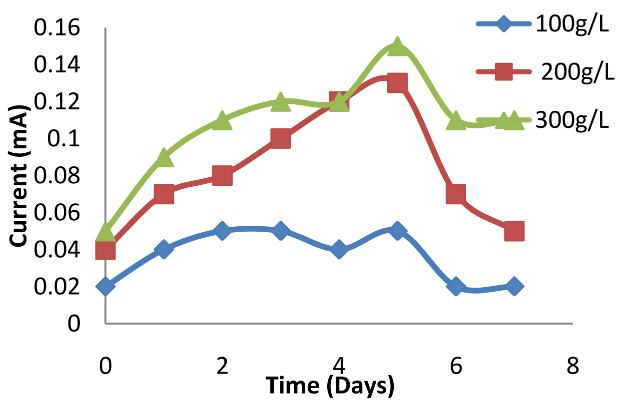

Figure 3b: *Effects of the substrate concentration on current generated in the MFC*

The performance of conventional anaerobic treatment processes, in the MFC demonstrated increasing output primarily as a result of the reduction of the cathode potential.The levels of interactions of temperature, substrate concentration and time were as well investigated in the 3-D plot relating the temperature-concentration-time dependency. Using the Design Expert, these relationships were represented in Figures 4a and 4b for voltage and current generated respectively.

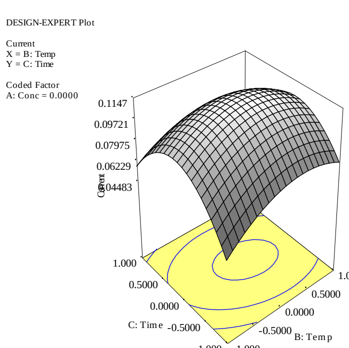

Figure 4a: *Effects of temperature and time on current generated in MFC*

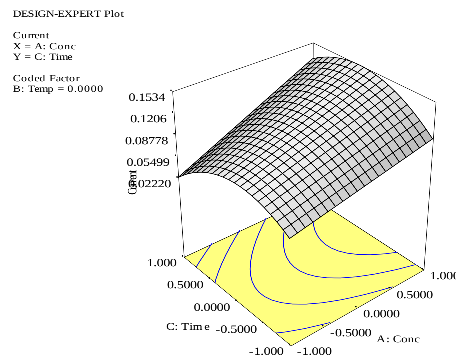

Figure 4b: *Effects of concentration and time on current generated.*

The assessment of the time-temperature dependence in current generated showed a temporary steady state of maximum attainable values of 0.115V Figure 4a. Over longer times the substrate concentration in the reactor changed due to substrate demand at the anode (unless continuously replenished). This in turn affected the substrate/electron transfer for voltage and current generation which decreased after a peak voltage of 1.10 V. The maximum was recorded by the interaction of the temperature and time Figure 4b while approximately 0.15mA was obtained for current in the MFC with 300g/l solution of the sample. The Ohmic losses were assumed to be relatively constant of proportionality between voltage and current for each set up.

4. CONCLUSION

The result revealed that poultry droppings or waste can be used as an alternative energy source by application in microbial fuel cells to generate electricity. The concentration of the samples determines the magnitude of power that could be generated and this is influenced by the ambient factors such as temperature. To attain comparatively high voltage and sustainable supply of power while MFC operates, the substrate bio-wastes need to be highly concentrated (paste-like) or replenished at regular intervals of time.

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