# Investigation of the potentials of poultry and piggery wastes for electricity generation using two configurations of microbial fuel cells

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**Abstract:** The potentials of poultry and piggery wastes for electricity production in terms of current, voltage and power generation using two different configurations of double-chambered microbial fuel cells (MFCs) under anaerobic and aerobic conditions of the anode chambers has been investigated. The two configurations of MFCs were designed, fabricated and investigated for electricity generation using the two different substrates under two different conditions of the anode chambers. In the first type, a double-chambered MFC of 5 litres capacity was constructed with the cathode and anode made of carbon electrodes. In the second type, multiple anodes attached in a circuit, were used in developing a multi-anode double-chambered MFC of the same capacity but with a common cathode made of carbon electrode. The generation of currents, voltages and power were observed with both designs under anaerobic and aerobic conditions of the anode chambers respectively. The voltages and currents were measured with a digital multimeter. The single anode (MFC-1) and the multi-anode (MFC-2) double-chambered MFCs were investigated for electricity generation under the two anodic conditions using poultry and piggery waste substrates. Preliminary experiments carried out showed that poultry waste substrate gave the highest voltage and current values of 0.986V and 0.198mA respectively obtained with the MFC-2 compared to 0.895V and 0.068mA obtained from piggery waste substrate, using MFC-2. The poultry waste with the highest potentials for electricity generation was used for further experiment in order to check the effect of everyday addition of glucose to the substrates. The experimental results showed a steady increase in current, voltage and power generation with peak values of 0.96mA, 1.22V and 1.12mW respectively.

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**Keywords:** Anaerobic and aerobic conditions, electricity generation, Microbial fuel cell, waste.

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## Introduction

Global energy crisis as result of increased depletion of fossil fuels has led to a serious search for alternate and sustainable energy resources. Energy is a vital area of research in the world at all times, and currently a range of energy sources are in use (Asif and Muneer, 2007). However, more focus is on renewable and sustainable energy solutions (Du et al., 2007; Lovely, 2006). The non-renewable resources of energy is depleting at a faster rate than new discoveries are made, coupled with growing awareness and concern over the global warming effect (Karmakar et al., 2010; Mahendra and Mahavarkar, 2013). A multi-faceted approach with high efficient energy transformations and ways to utilize the alternate renewable energy sources is needed to alleviate the energy crisis. New approach of electricity production from renewable resources without a net carbon dioxide emission is much desired (Davis and Higson, 2007; Lovely, 2006). Fuel cells are one of the most important areas of research for sustainable production of electricity (Lovely, 2006; Potter, 1912). The main aspect of fuel cell research is to reduce the cost and simplify the implementation conditions (Karmakar et al., 2010). Microbial fuel cells (MFCs) are bioelectrochemical systems (bioreactors) that convert the chemical energy in organic matter into electricity by means of metabolic activity (catalysis) of the aerobic and anaerobic microbes (Kim et al., 2002; Liu et al., 2004; Logan, 2009; Logan and Regan, 2006). Microbes such as *Actinobacillus succinogenes* (Park and Zeikus, 2000), *Geobacter sulfurreducens* (Bond and Lovley, 2003), *Escherichia coli* (Grzebyk and Pozniak, 2005; Ieropoulos et al., 2005), *Desulfovibrio desulfuricans* (Ieropoulos et al., 2005; Park et al., 1997), *Rhodoferax ferrireducens* (Chaudhuri and Lovley, 2003; Liu et al., 2006), *Clostridium butyricum* (Niessen et al., 2004; Park et al., 2001), *Klebsiella pneumonia* (Menicucci et al., 2006; Rhoads et al., 2005) and so on; can be used in MFCs to generate electricity while accomplishing the biodegradation of organic matters (Oh and Logan, 2005; Park and Zeikus, 2000; Rabaey and Verstraete, 2005). The decomposition of organic compounds leads to natural production of electrons that enter into the circuit via the anode (Potter, 1912); and can be transferred in two ways: either with the help of soluble chemical mediators or the electron is directly deposited on the anode by bacterial biofilm. MFCs have gained significance in the last few decades due to its applications for different purposes such as electricity generation from biomass wastes, biohydrogen production, biosensors and wastewater treatment (Karmakar et al., 2010).

MFC consists of anode and cathode separated by a proton exchange membrane or a salt bridge. In the anode chamber, the substrate is oxidized by microorganisms generating protons and electrons. The electrons are transferred through an external circuit, while the protons diffuse through the solution to the cathode, where electrons combine with protons and oxygen to form water (Karmakar et al., 2010; Mahendra and Mahavarkar, 2013; Zhuwei et al., 2007). There are two kinds of microbial fuel cells: (i) mediator and (ii) mediator-less. Two

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general designs (i.e. single and multiple chambered MFCs) are commonly available (Zhuwei et al., 2007). In mediator microbial fuel cell, the bacteria are electrochemically inactive. The bacteria digest the organic matter and create electrons. The electron transfer from microbial cells to the electrode is facilitated by mediators such as humic acid, thionine, methyl blue, methyl viologen, neutral red and so on (Park and Zeikus, 2000; Rabaey et al., 2004). Most of the mediators available are expensive and toxic to bacteria. Mediator-less microbial fuel cells do not require a mediator but uses electrochemically active bacteria to transfer electrons to the electrode (Bond and Lovley, 2003; Mahendra and Mahavarkar, 2013). The electrode materials, proton exchange membranes (PEM) or salt bridge and operation conditions of anode and cathode have important effect on MFCs. The power output and coulombic efficiency of MFC are significantly affected by the types of microbe in its anodic chamber, configuration of the MFC and operating conditions (Chaudhuri and Lovley, 2003; Ieropoulos et al., 2003; Liu et al., 2005; Zhuwei et al., 2007). The electrode material determines the diffusivity of oxygen in single chambered MFCs and the power loss of fuel cell in terms of internal resistance (Oh and Logan, 2005). The ratio of membrane surface area to system volume is critical to the system performance. Alternative membranes such as porous polymers and glass wools have been tested but are not utilized by researchers most of the time (Rozendal et al., 2006). Operating condition such as Dissolved Oxygen (DO) content is important parameter since higher DO facilitates diffusion of more oxygen into anode compartment through the porous membrane. Oxygen saturated catholytes are found to be the optimum (Oh et al., 2004). Anode uses low DO but Cathode uses high DO. Fuel or substrate concentration also plays an important role. Though higher fuels are preferrable but most of the time it is inhibitory to microorganism. So a proper feed rate should be maintained in continuous systems and proper feed concentrations in batch mode of working.

Potter in 1910 demonstrated the earliest MFC concept (Ieropoulos et al., 2005). He produced electrical energy from living cultures of *Escherichia* coli and *Saccharomyces* using platinum electrodes (Potter, 1912). Much interest was not generated in that concept until 1980s when it was discovered that current density and the power output could be greatly enhanced by the addition of electron mediators (Zhuwei

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et al., 2007). But recently several studies and research in this subject have undergone many interesting stages worth reviewing and taking note of, in order to provide a current understanding of the trend in this discipline and to point out the future direction. (Mahendra and Mahavarkar, 2013) compared the potentials of single chamber and double chambered MFCs for domestic and dairy wastewater treatment and electricity generation. They observed that the single chambered MFC proved to be more efficient by producing maximum current of 0.84 mA and 1.02mA whereas double chambered MFC produced maximum current of 0.56mA and 0.58mA from full strength (100%) domestic and dairy wastewater concentrations respectively. Also, the chemical oxygen demand (COD) removal efficiency achieved in double chambered MFC was 88.4% and 86.42% for 100% domestic and dairy wastewater concentrations respectively when compared with single chambered MFC which attained 86.6% and 84.8% respectively for 100% domestic and dairy wastewater concentrations respectively. (Min and Logan, 2004) designed a flat plate MFC with a single electrode/PEM assembly. The anodic chamber can be fed with wastewater or other organic biomass and dry air can be pumped through the cathodic chamber without any liquid catholyte, both in a continuous flow mode. (Park and Zeikus, 2003) designed a one compartment MFC consisting of an anode in a rectangular anode chamber coupled with a porous air-cathode that is exposed directly to the air. (Tartakovsky and Guiot, 2006) presented another MFC design inspired by the same general idea but with a rectangular container and without a physical separation achieved by using glass wool and glass beads. The feed stream is supplied to the bottom of the anode and the effluent passes through the cathodic chamber and exits at the top continuously. Liu and Logan (2004) designed an MFC consisting of an anode placed inside a plastic cylindrical chamber and a cathode placed outside. The anode was made of carbon paper without wet proofing. The cathode was either a carbon electrode/PEM assembly fabricated by bonding the PEM directly onto a flexible carbon-cloth electrode, or a stand-alone rigid carbon paper without PEM.(Chaudhuri and Lovley, 2003) reported that R. ferrireducens could generate electricity with an electron yield as high as 80%. Higher electron recovery as electricity of up to 89% was also reported (Rabaey et al., 2003). An extremely high Coulombic efficiency of 97% was

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reported during the oxidation of formate with the catalysis of Pt black (Rosenbaum et al., 2006). However, MFC power generation is still very low (Delong and Chandler, 2002; Tender et al., 2002), that is the rate of electron abstraction is very low. One feasible way to solve this problem is to store the electricity in rechargeable devices and then distribute the electricity to end-users (Ieropoulos et al., 2003). Power output is much greater using ferricyanide as the electron acceptor in the cathodic chamber. So far, reported cases with very high power outputs such as 7200 mW/m$^2$, 4310 mW/m$^2$ and 3600 mW/m$^2$ all used ferricyanide in the cathodic chamber (Oh et al., 2004; Rabaey et al., 2004; Schroder et al., 2003), while less than 1000 mW/m$^2$ was reported in studies using DO regardless of the electrode material. This is likely due to the greater mass transfer rate and lower activation energy for the cathodic reaction offered by ferricyanide (Oh et al., 2004). Using hydrogen peroxide solution as the final electron acceptor in the cathodic chamber increased power output and current density according to (Tartakovsky and Guiot, 2006).

In this present study, an effort has been made to investigate the potentials of poultry and piggery wastes for generation of electricity using two different configurations of double-chambered microbial fuel cells (MFCs) under anaerobic and aerobic conditions of their anode chambers respectively. Thus, a double-chambered MFC was set up in two configurations: one having a single anode with a single cathode (denoted as MFC-1) while the other has multiple anodes with a single cathode (MFC-2). The two MFC designs were operated under anaerobic and aerobic conditions of their anode chambers respectively and the potentials of electricity generation in terms of current, voltage and power generation using the two waste substrates were investigated and compared. Also, the waste with the highest potential for electricity generation was used for further experiment in order to check the effect of everyday addition of glucose to the substrate.

## 2.0 Materials and method

### 2.1 Collection of waste samples

The poultry and the piggery wastes were collected from the Faculty of Vertinary Medicine's poultry and piggery farms respectively at the University of Nigeria Nsukka.

### 2.2 Substrate preparation from the wastes

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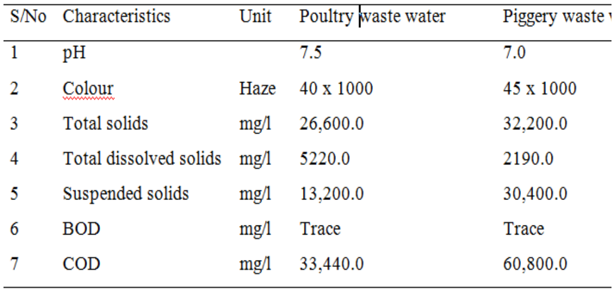
The wastes collected were measured using a digital weighing balance in order to get a uniform sample weight. 1000g (1kg) of each of the waste samples collected was diluted with 3 litres of distilled water and were used as substrates for the experiments. The samples were collected on the day of the setup. The waste substrate, in each case, was used initially for the entire MFCs' preliminary tests without any added nutrient, and was fed to the anode chamber as fuel while distilled water was fed to the cathode chamber for each of the experiments conducted using either of the MFCs. Both substrate samples were kept in a refrigerator at $4^0$C before use. After the preliminary experiments, the waste with the highest potential for electricity generation was then used for further experiment in order to check the effect of everyday addition of glucose to the substrate. Proximate analysis was conducted to determine the characteristics of the piggery and poultry waste substrates before experimentation. Table 1 presents the results of the proximate analysis.

Table 1: Characteristics of the piggery and poultry waste water.



| S/No | Characteristics | Unit | Poultry waste water | Piggery waste |
|---|---|---|---|---|
| 1 | pH | | 7.5 | 7.0 |
| 2 | Colour | Haze | 40 x 1000 | 45 x 1000 |
| 3 | Total solids | mg/l | 26,600.0 | 32,200.0 |
| 4 | Total dissolved solids | mg/l | 5220.0 | 2190.0 |
| 5 | Suspended solids | mg/l | 13,200.0 | 30,400.0 |
| 6 | BOD | mg/l | Trace | Trace |
| 7 | COD | mg/l | 33,440.0 | 60,800.0 |

## 2.3 MFCs' fabrication

Two configurations of MFC reactors were fabricated and applied in this study. One was a double-chambered MFC with a single anode and a single cathode; and the other was also a double-chambered MFC but with a triple anode and a single cathode according to (Banik et al., 2012). The reactors were fabricated using non-reactive plastic containers with total volumes of 5litres and working volumes of 4litres each. Carbon electrodes were used as both the anode and cathode materials. The arrangement of the carbon electrodes was made in such a way as to provide the maximum surface area for the development of biofilm on the anode. The electrodes were connected using copper wires instead of agar salt bridge in order to reduce cost and examine the effect of using copper wires. The electrodes were placed in the chambers; with the anode chamber made airtight (anaerobic), while holes were made in the cover of the cathode chamber (aerobic). (Logan et al., 2007) have reported the advantage of air-cathode MFC (compared with the cathode suspended in water) as oxygen transfer to the cathode occurs directly from air, and thus oxygen does not have to be dissolved in water. The abundant electron acceptor i.e., oxygen availability in

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air is the reason for the higher current generation. The double-chambered MFC with a single anode configuration consists of two plastic containers. One container was used as anode chamber and the other as cathode chamber according to(Karmakar et al., 2010) (figure 1). While the double-chambered MFC with a triple anode consists, also, of two plastic containers and was setup according to (Banik et al., 2012) (figure 2). In this configuration, one container was used as the anode and the other as the cathode chamber. Similarly, another fabrication was done for both configurations, but in this case, both the anode and cathode chambers were made aerobic by drilling holes in the covers of their chambers in order to determine the effect of electricity generation from the MFCs under aerobic condition of the anode. Figures 1 and 2 present the schematic diagrams of the experimental setups for both MFC configurations while figure 3 is the picture of the set up.

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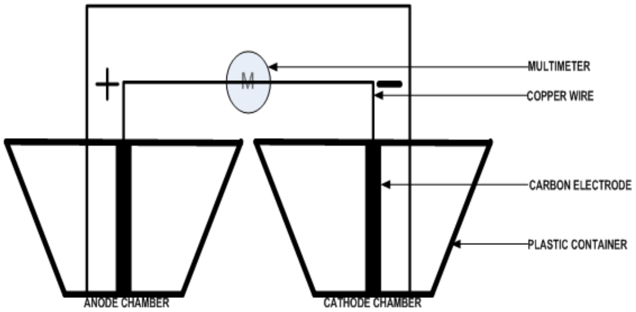

Figure 1: Experimental setup for the double-chambered MFC with single anode and single cathode configuration (MFC-1)

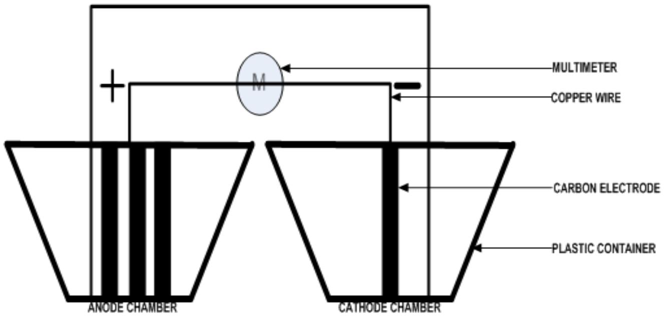

Figure 2: The experimental setup for the double-chambered MFC with a triple and single cathode configuration (MFC-2)

(a) MFC-2 (b) MFC-1

Figure 3: The pictures of the experimental setup

## 2.4 The operation of the MFCs

The study was conducted by feeding poultry and piggery waste substrates separately to the two developed MFC configurations denoted as MFC-1 and MFC-2 respectively. In all cases, the anode chamber was filled with the substrate and the cathode chamber (where oxygen was used as the electron acceptor) was filled with distilled water instead of KCl solution (catholyte) according to (Mahendra and Mahavarkar, 2013). The internal wiring of the anode and cathode chambers was connected to a multimeter to complete the circuit. The entire setup was left for the next day for stabilization and the reading in the multimeter was noted every 24hours for 7 days of operation.

### 2.5 Analysis

Voltages and currents generated were measured using a digital multimeter, and converted to power, P, (miliWatts) and power density, $P_d$ (mW/m$^2$) according to the equations: $P = I \times V$ and $P_d = IV/A$; where I (mA) is the current, V (Volts) is the voltage, and A (m$^2$) the surface area of the projected anode. Power density, $P_d$, was analyzed according to (Rabaey and Verstraete, 2005).

### 3.0 Results and discussion

The designing of the MFCs employed was cost effective as copper wires were used for transfer of protons instead of a sophisticated membrane. The use of copper wires reduced the cost significantly and provided satisfactory results. The two configurations of the double-chambered MFCs: (i) MFC-1 and (ii) MFC-2 were run parallel. The surface areas of the electrodes used in this experiment are 0.01142m$^2$ and 0.03426m$^2$ for the single anode (MFC-1) and triple anode (MFC-2) microbial fuel cells respectively. The MFCs were first operated by feeding poultry and piggery waste substrates of the same concentration separately, and without any additional nutrient to support the formation of biomass and subsequent generation of electricity. The MFCs were continuously monitored during the experiment and average daily readings were taken after each 24 hours, inoculation time was considered as time 0. The readings were noted down for 7 days of the MFCs' operation. Preliminary experiments conducted using the MFCs showed that electricity could be generated from the two different waste substrates. The potentials for electricity generation from poultry and piggery wastes were observed for the two configurations of double-chambered MFCs using their waste water samples as the anodic substrates and distilled water as the catholyte for each case under two experimental conditions (i.e. anaerobic and aerobic conditions of the anode chambers). Currents and voltages were measured for the same concentration of both waste substrates using the multimeter. After seven (7) days of monitoring, observation and operation of the developed MFCs for each of the experimental setups under the two conditions of the anode chambers, the following results, (as presented in tables 2, 3. 4, and 5 below), were obtained:

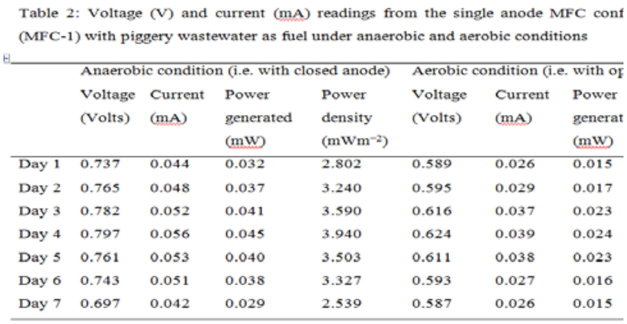
Table 2: Voltage (V) and current (mA) readings from the single anode MFC conf
(MFC-1) with piggery wastewater as fuel under anaerobic and aerobic conditions

| | Anaerobic condition (i.e. with closed anode) | | | | Aerobic condition (i.e. with op | | |
|---|---|---|---|---|---|---|---|
| | Voltage (Volts) | Current (mA) | Power generated (mW) | Power density (mWm⁻²) | Voltage (Volts) | Current (mA) | Power generat (mW) |
| Day 1 | 0.737 | 0.044 | 0.032 | 2.802 | 0.589 | 0.026 | 0.015 |
| Day 2 | 0.765 | 0.048 | 0.037 | 3.240 | 0.595 | 0.029 | 0.017 |
| Day 3 | 0.782 | 0.052 | 0.041 | 3.590 | 0.616 | 0.037 | 0.023 |
| Day 4 | 0.797 | 0.056 | 0.045 | 3.940 | 0.624 | 0.039 | 0.024 |
| Day 5 | 0.761 | 0.053 | 0.040 | 3.503 | 0.611 | 0.038 | 0.023 |
| Day 6 | 0.743 | 0.051 | 0.038 | 3.327 | 0.593 | 0.027 | 0.016 |
| Day 7 | 0.697 | 0.042 | 0.029 | 2.539 | 0.587 | 0.026 | 0.015 |

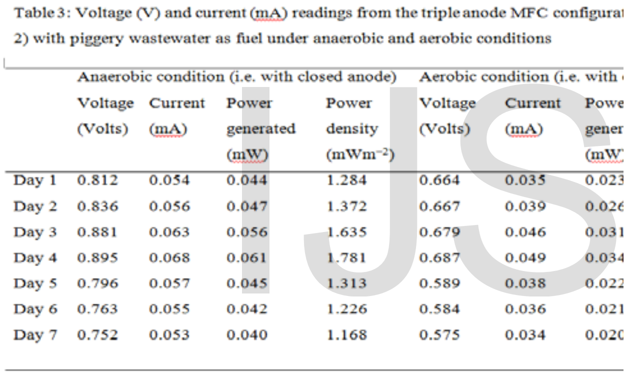
Table 3: Voltage (V) and current (mA) readings from the triple anode MFC configurat
2) with piggery wastewater as fuel under anaerobic and aerobic conditions

| | Anaerobic condition (i.e. with closed anode) | | | | Aerobic condition (i.e. with | | |
|---|---|---|---|---|---|---|---|
| | Voltage (Volts) | Current (mA) | Power generated (mW) | Power density (mWm⁻²) | Voltage (Volts) | Current (mA) | Powe gener (mW |
| Day 1 | 0.812 | 0.054 | 0.044 | 1.284 | 0.664 | 0.035 | 0.023 |
| Day 2 | 0.836 | 0.056 | 0.047 | 1.372 | 0.667 | 0.039 | 0.02 |
| Day 3 | 0.881 | 0.063 | 0.056 | 1.635 | 0.679 | 0.046 | 0.031 |
| Day 4 | 0.895 | 0.068 | 0.061 | 1.781 | 0.687 | 0.049 | 0.034 |
| Day 5 | 0.796 | 0.057 | 0.045 | 1.313 | 0.589 | 0.038 | 0.022 |
| Day 6 | 0.763 | 0.055 | 0.042 | 1.226 | 0.584 | 0.036 | 0.021 |
| Day 7 | 0.752 | 0.053 | 0.040 | 1.168 | 0.575 | 0.034 | 0.02 |

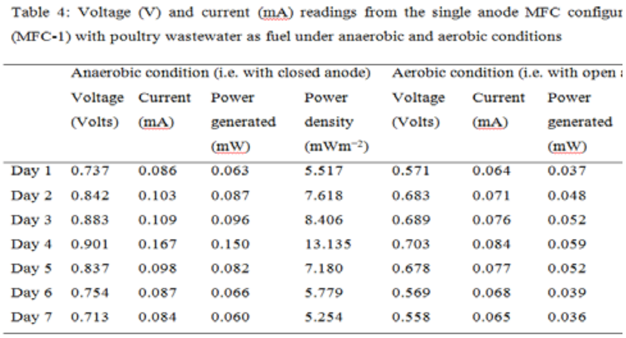
Table 4: Voltage (V) and current (mA) readings from the single anode MFC configur
(MFC-1) with poultry wastewater as fuel under anaerobic and aerobic conditions

| | Anaerobic condition (i.e. with closed anode) | | | | Aerobic condition (i.e. with open | | |
|---|---|---|---|---|---|---|---|
| | Voltage (Volts) | Current (mA) | Power generated (mW) | Power density (mWm⁻²) | Voltage (Volts) | Current (mA) | Power generated (mW) |
| Day 1 | 0.737 | 0.086 | 0.063 | 5.517 | 0.571 | 0.064 | 0.037 |
| Day 2 | 0.842 | 0.103 | 0.087 | 7.618 | 0.683 | 0.071 | 0.048 |
| Day 3 | 0.883 | 0.109 | 0.096 | 8.406 | 0.689 | 0.076 | 0.052 |
| Day 4 | 0.901 | 0.167 | 0.150 | 13.135 | 0.703 | 0.084 | 0.059 |
| Day 5 | 0.837 | 0.098 | 0.082 | 7.180 | 0.678 | 0.077 | 0.052 |
| Day 6 | 0.754 | 0.087 | 0.066 | 5.779 | 0.569 | 0.068 | 0.039 |
| Day 7 | 0.713 | 0.084 | 0.060 | 5.254 | 0.558 | 0.065 | 0.036 |

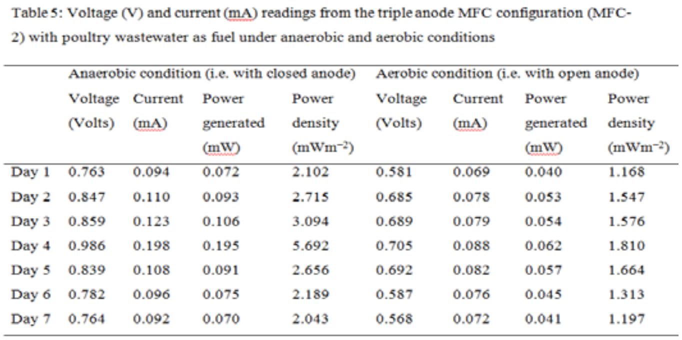
Table 5: Voltage (V) and current (mA) readings from the triple anode MFC configuration (MFC-2) with poultry wastewater as fuel under anaerobic and aerobic conditions

| | Anaerobic condition (i.e. with closed anode) | | | | Aerobic condition (i.e. with open anode) | | | |
|---|---|---|---|---|---|---|---|---|
| | Voltage (Volts) | Current (mA) | Power generated (mW) | Power density (mWm⁻²) | Voltage (Volts) | Current (mA) | Power generated (mW) | Power density (mWm⁻²) |
| Day 1 | 0.763 | 0.094 | 0.072 | 2.102 | 0.581 | 0.069 | 0.040 | 1.168 |
| Day 2 | 0.847 | 0.110 | 0.093 | 2.715 | 0.685 | 0.078 | 0.053 | 1.547 |
| Day 3 | 0.859 | 0.123 | 0.106 | 3.094 | 0.689 | 0.079 | 0.054 | 1.576 |
| Day 4 | 0.986 | 0.198 | 0.195 | 5.692 | 0.705 | 0.088 | 0.062 | 1.810 |
| Day 5 | 0.839 | 0.108 | 0.091 | 2.656 | 0.692 | 0.082 | 0.057 | 1.664 |
| Day 6 | 0.782 | 0.096 | 0.075 | 2.189 | 0.587 | 0.076 | 0.045 | 1.313 |
| Day 7 | 0.764 | 0.092 | 0.070 | 2.043 | 0.568 | 0.072 | 0.041 | 1.197 |

The currents, voltages and power generation showed a gradual increase for few days, and then declined. This variation was due to the availability of less oxidizable substrates in the waste samples. The peak currents, voltages and power generation were observed, in all cases, on the 4th day of the preliminary experiments, as can be clearly observed in figures 4 to 17 below. After the 4th day, the peak values started decreasing continuously. The currents, voltages and power generation from the poultry waste substrate samples were higher than those of the piggery waste substrate samples, in all cases, especially under anaerobic condition of the anode chambers of the MFCs (figures 4 to 17). Thus poultry waste substrate gave higher potentials for electricity generation than the piggery substrate in all cases, especially under the anaerobic condition of the anode chambers. This shows that the poultry waste contains more oxidizable and electron-rich substrate than the piggery waste. The currents, voltages and power

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generation were higher in MFC-2, in all cases, when compared with MFC-1. This was due to a higher electrode surface area as a result of multiple anodes. But then, it was observed that the power density of MFC-2 was lower when compared to that of MFC-1 due to increased surface area of the electrode (figures 18 and19). Further experiments conducted using the poultry waste substrates with the addition of glucose showed a steady increase in currents, voltages and power generation with peak values of 0.96mA, 1.22V and 1.12mW respectively. This increase is due to addition of glucose that resuscitated the nutrients in the substrates and affected positively the metabolic activities of the microbes.

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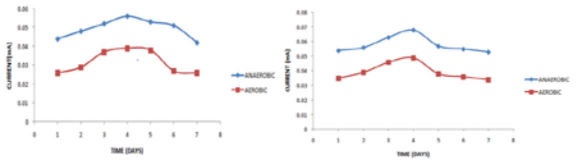
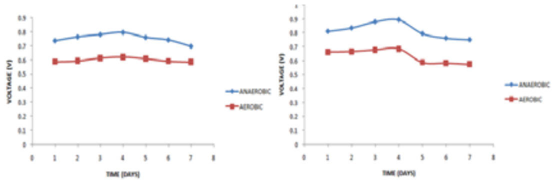


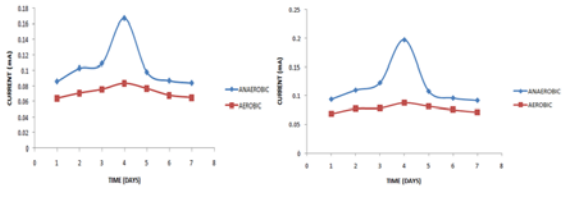
(a) MFC-1 (b) MFC-2

Figure 4: Graphs of currents generated (mA) against time of production (days) for the two MFC configurations with piggery wastewater as substrate under anaerobic and aerobic conditions of the anodes



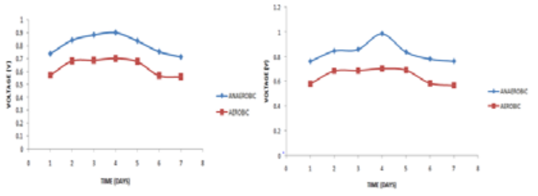
(a) MFC-1 (b) MFC-2

Figure 5: Graphs of Voltages generated (V) against time of production (days) for the two MFC configurations with piggery waste water as substrate under anaerobic and aerobic conditions of the anodes



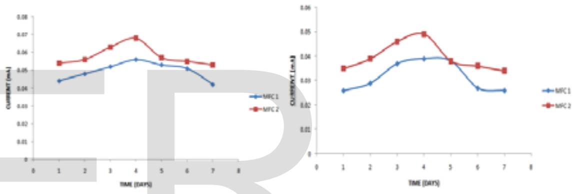
(a) MFC-1 (b) MFC-2

Figure 6: Graphs of currents generated (mA) against time of production (days) for the two MFC configurations with poultry waste water as substrate under anaerobic and aerobic conditions of the anodes



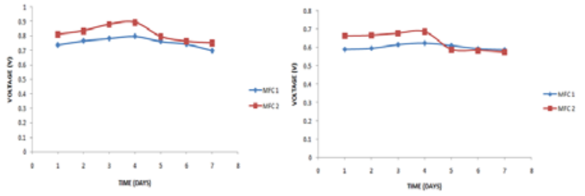
(a) MFC-1 (b) MFC-2

Figure 7: Graphs of Voltages generated (V) against time of production (days) for the two MFC configurations with poultry waste water as substrate under anaerobic and aerobic conditions of the anodes



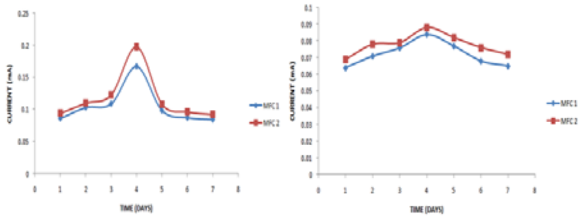
(a) Anaerobic condition (b) Aerobic condition

Graph 8: Graphs of currents generated (mA) against time of production (days) for both MFC configurations with piggery waste waters as substrate under anaerobic and aerobic conditions



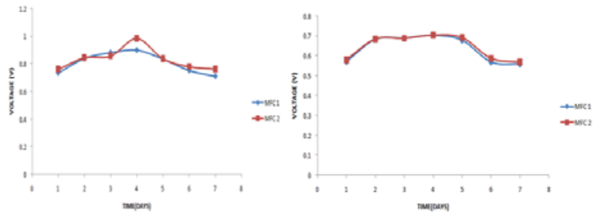
(a) Anaerobic condition (b) Aerobic condition

Graph 9: Graphs of Voltages generated (V) against the time of production (days) for both MFC configurations with piggery waste waters as substrate under anaerobic and aerobic conditions



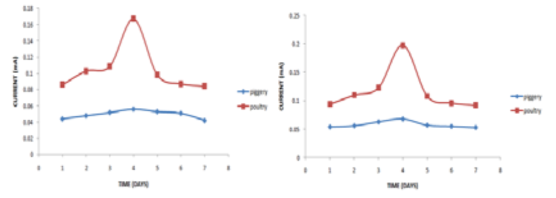
(a) Anaerobic condition (b) Aerobic condition

Graph 10: Graphs of currents generated (mA) against time of production (days) for both MFC configurations with poultry waste waters substrate under anaerobic and aerobic conditions



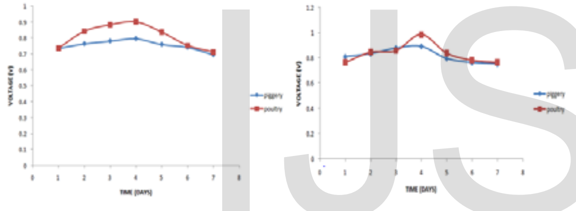
(a) Anaerobic condition (b) Aerobic condition

Graph 11: Graphs of Voltages generated (V) against time of production (days) for both MFC configurations with poultry waste waters as substrate under anaerobic and aerobic conditions



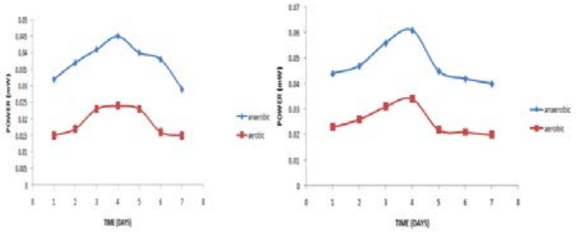
(a) MFC-1 (b) MFC-2

Graph 12: Graphs of currents generated (mA) against time of production (days) for piggery and poultry waste water for MFC-1 and MFC-2 configurations for anaerobic condition only



(a) MFC-1 (b) MFC-2

Graph 13: Graph of voltage (V) against time of production (days) for piggery and poultry waste water for MFC-1 and MFC-2 configurations under anaerobic condition only



(a) MFC-1 (b) MFC-2

Figure 14: Graphs of power generated (mW) against time of production (days) for MFC-1 and MFC-2 configurations from piggery waste substrate for anaerobic and aerobic conditions of the anodes

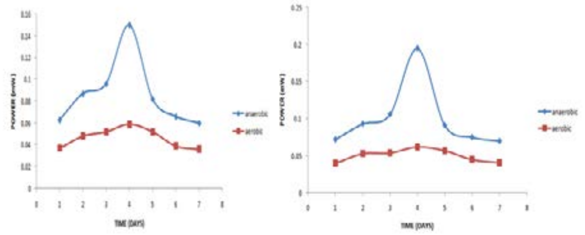
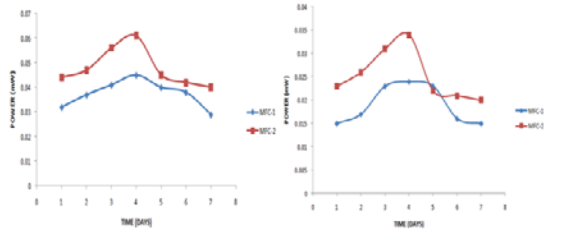


Figure 15: Graphs of power generated (mW) against time of production (days) for MFC-1 and MFC-2 configurations from poultry waste substrate for anaerobic and aerobic conditions of the anodes



(a) Anaerobic condition (b) Aerobic condition

Figure 16: Graphs of power generated (mW) against time of production (days) for MFC-1 and MFC-2 configurations from piggery waste substrate for anaerobic and aerobic conditions of the anodes respectively

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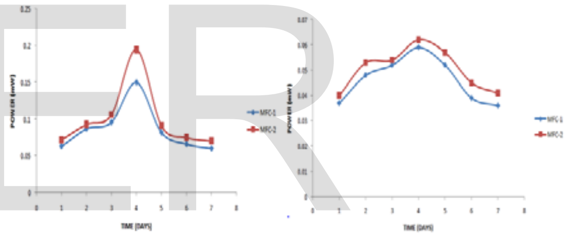
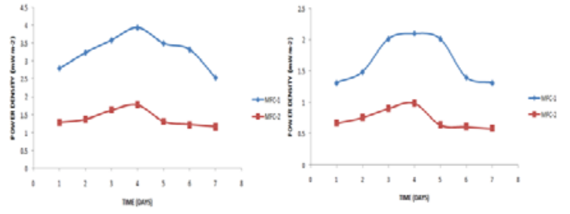


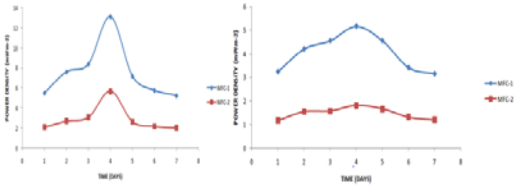
(a) Anaerobic condition (b) Aerobic condition

Figure 17: Graphs of power generated (mW) against time of production (days) for MFC-1 and MFC-2 configurations from poultry waste substrate for anaerobic and aerobic conditions of the anodes respectively



(a) Anaerobic condition (b) Aerobic condition

Figure 18: Graphs of power density (mWm$^{-2}$) against time of production (days) for MFC-1 and MFC-2 configurations from piggery waste substrate for anaerobic and aerobic conditions of the anodes respectively



(a) Anaerobic condition (b) Aerobic condition

Figure 19: Graphs of power density ($mWm^{-2}$) against time of production (days) for MFC-1 and MFC-2 configurations from poultry waste substrate for anaerobic and aerobic conditions of the anodes respectively

## 4.0 Conclusion

This study has investigated the potentials of electricity generation from piggery and poultry wastes using two configurations of MFCs under anaerobic and aerobic conditions. Copper wires were used for connecting the two chambers instead of a proton exchange membrane or a salt bridge. In all cases of the experiments carried out under the anaerobic and aerobic conditions of the anode chambers of the developed MFCs, the two configurations of the MFCs produced electrical currents, voltages and power at varying rates depending on the availability of the oxidizable and electron-rich substrates. It was observed that the currents, voltages and power generated increased steadily from day 1with both configurations of MFCs and the peak values were obtained on the 4th day of the experiments before the MFC systems started experiencing a voltage and current drop due to the exhaustion of nutrients in the substrates by the micro organisms. It was also noted from the experiments that micro organisms function better under anaerobic condition than aerobic condition of the anodes due to the increased metabolic activities of the anaerobic micro organisms in the substrate. Thus, the anaerobic conditions of both configurations of the developed MFCs gave higher voltage and current readings throughout the entire experiments as can be observed in figures 4 to 17 above. It was also very clear that the MFC-2, with a triple anode chamber, gave higher current, voltage and power values than the MFC-1, with a single anode chamber, due to an increased surface area for reactions hence enhancing the electrode’s kinetics. Since the Ohmic losses of any MFC are directly proportional to the resistance of the electrodes, thus increasing the surface areas of reactions of the electrodes reduces the resistance which in turn reduces the Ohmic losses. From the experiments carried out, it was observed that poultry waste water samples gave the highest voltage and current values of 0.986V and 0.198mA respectively which were gotten from MFC-2 compared to 0.895V and 0.068mA obtained from piggery waste water, using MFC-2.

MFCs are a promising new technology for generation of electrical energy. The power density produced

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determines its performance, which is the most important aspect of the technology. Power density is affected by the kind of MFC reactor, bacterial culture, size of electrode, the substrates, and the oxidants. The Oxidation of the substrate, moving electrons to the electrode, internal resistance, flow of proton, and reaction of the cathode are the parameters governing MFC performance (Agarry et al., 2016; Chae et al., 2008; Eric, 2006; Heitner-wirguin, 1996). This technology is close to practical use but not there yet. Overcoming high resistance in MFCs remains a major challenge. The development of less expensive materials for enhancing MFC technology to produce highly sustainable efficient electrical energy is another challenge. But in the current state, MFCs can be used to power low power electrical appliances especially in rural areas (Ieropoulos et al., 2003; Karmakar et al., 2010).

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