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The effect of electrodes on the voltage generation of microbial fuel cell

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Abstract: Microbial fuel cell (MFC) is a device that coverts the chemical energy contents of organic matter to electrical energy by the catalytic action of microorganisms. Cow dungs as organic substrates were used in three sets of dual chambered MFCs to study the effects of electrodes on the open circuit voltage (OCV) generation of MFC. The anode and cathode compartments were connected using a proton exchange membrane, 1 kg of the cow dung diluted with 500 ml of water was introduced in the anode compartment of each of the setups. The electrode configurations for set-up 1, 2 and 3 respectively were Carbon-Carbon(C-C), carbon-copper(C-Cu) and carbon-zinc(C-Zn). Samples for microbial load count were collected every two days from the anode compartment of the MFC and analyzed using standard microbiological methods. The OCV of the three setups were measured daily for two weeks using a digital multimeter. The microbial load ranged from 4.2×10^4 to 8.5×10^4 CFU/ml for bacteria and 2.1×10^2 to 2.3×10^3 CFU/ml for fungi. The range (average) of the OCV obtained from the set-ups were 0.06 to 0.72 V (0.42 V) for the C–C; 0.02 to 0.67 V (0.26 V) for C-Cu and 0.11 to 0.78 V (0.39 V) for the C-Zn. The OCV for the C-C electrode combination showed an increasing trend while the OCV of C-Cu and C-Zn showed decreasing trends with increasing number of days. The C-C electrode combination gave the best OCV.

Keywords: microbial fuel cell, open circuit voltage, electrodes, organic substrate

1. INTRODUCTION

Technological advancement, population and economy growth has led to increase in the demand of energy. Energy demand has been projected to grow by more than 50 % by 2025 [1]. Current world energy consumption is basically acquired from fossil fuel, which aside its harmful environmental effect has proved to be an economic and efficient source of energy [2 - 4]. Depletion and environmental impact of fossil fuel are some factors that are driving the development of alternate energy sources. Renewable energy sources hold great potentials for the production of cleaner and less carbon intensive energy. Bioenergy sources are regarded as one of the renewable and sustainable means of alleviating the energy crises as well as maintaining a cleaner environment [2]. Microbial fuel cell (MFC) is a bioenergy device that converts the chemical energy in organic substrates into electrical energy through the catalytic action of the microorganisms [5 – 6]. It is typically made up of an anode and a cathode chamber. The organic substrates in the anode chamber is oxidized by the microbes with the release of electrons and protons. The electrons produced are transferred to the anode and flow to the cathode through an external circuit [7]. The protons, through a proton exchange membrane (PEM) diffuse to the cathode chamber and combine with the electrons in the presence of oxygen to form water [8 – 9]. The transfer of electrons in MFC can be aided by mediators while some MFCs called the mediator-less MFCs operate solely on the actions of the microorganisms [7 – 8].

There is a hurdle of low power output of MFC to be surmounted in order to facilitate the scaling up of MFCs. This challenge can be overcome by studying the many factors affecting its performance and much work has not been done on studying these factors in the recent times [9]. In this work, the effect of different electrodes on the open circuit voltage (OCV) of mediator-less, dual chambered MFC with cow dungs as organic substrate was investigated.

2. MATERIALS AND METHODS

Three sets of H-shaped, dual-chamber MFCs operated in batch method were constructed for this study. Each setup was made-up of two plastic containers each of diameter 19.5 cm and height 21.5 cm, one for the anode chamber and the other for the cathode chamber. Holes were drilled on the lower parts of the containers and PVC pipes were fitted into the holes using glue. An outlet hole drilled on each of the anode chambers was fitted with a control tap to enable the collection of samples for microbial analysis. The anode chambers were joined to the cathode chambers through a salt bridge in a pipe of 20 mm diameter and length 7 cm. The salt bridge served as the PEM for the experiment. The salt bridges were prepared using nutrient agar, sodium chloride and distilled water. A 7.5 g of the agar and 50 g of NaCl were added to 500 ml of distilled water, the mixture was properly mixed and was heated in an autoclave at a temperature of 121°C for 15 minutes. The mixture was allowed to cool after which the jelly-like mixture was poured into the PVC pipes cut for the salt bridge.

The three anode chambers were each loaded with 1 kg of cow dung and 500 ml water. Setup-1 was completed by connecting a carbon electrode in the anode and cathode chambers, setup-2 was connected with carbon electrode in the anode chamber and zinc electrode in the cathode

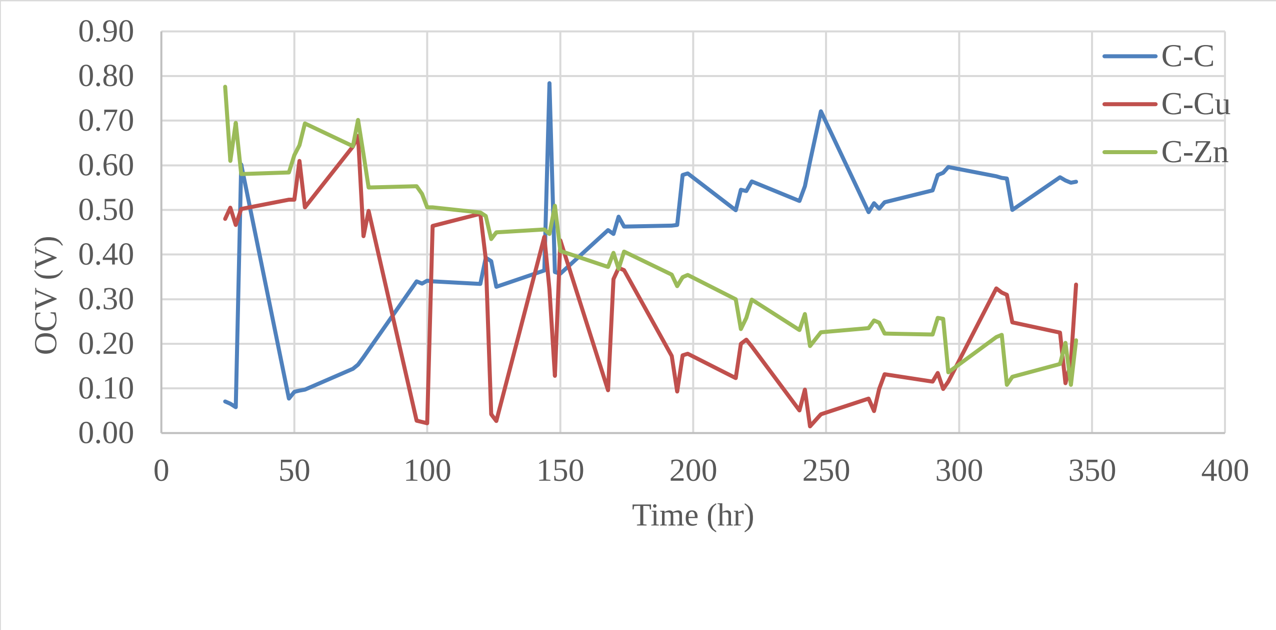

Fig. 4. Open circuit voltages for the different electrode configurations

Table 1: Total Microbial Count of Cow Dung

TIME (HOURS)	BACTERIAL LOAD (CFU/ML)	FUNGAL LOAD (SFU/ML)
1	6.5 X 10^4	2.3 X 10^3
3	7.2 X 10^4	1.9 X 10^3
5	8.5 X 10^4	2.3 X 10^2
7	6.8 X 10^4	2.1 X 10^2
9	7.6 X 10^4	-
11	4.8 X 10^4	-
13	4.2 X 10^4	-

Table 2: Bacterial succession during energy generation from cow dungs

TIME (DAYS)	ISOLATED BATERIA
1	*Bacillus cereus, Bacillus subtilis, Pseudomonas aeruginosa, Escherichia coli, Staphylococcus aureus, Salmonella* sp, *Enterobacter cloacae, Lactobacillus* sp.
3	*Enterobacter cloacae, Proteus mirabilis, Bacillus subtilis, Staphylococcus aureus, Lactobacillus* sp., *Pseudomonas aeruginosa, Escherichia coli*
5	*Bacillus subtilis, Pseudomonas aeruginosa, Proteus mirabilis, Enterobacter cloacae, Escherichia coli*
7	*Bacillus subtilis, Pseudomonas aeruginosa, Proteus mirabilis, Enterobacter cloacae, Escherichia coli*
9	*Enterobacter cloacae, Bacillus subtilis, Pseudomonas aeruginosa*
11	*Enterobacter cloacae, Bacillus subtilis*
13	*Enterobacter cloacae, Bacillus subtilis*

chamber while set-up 3 was connected with carbon electrode in the anode chamber and copper electrode in the cathode chamber. The diameters and heights of the electrodes were 1.5 cm and 15.3 cm, 0.5 cm and 13.2 cm, 0.8 cm and 12.8 cm for carbon, copper and zinc electrodes, respectively. Cables were connected on each electrode and passed through the holes drilled on the lids of the plastic containers. The anode chambers were tightly closed to maintain an anaerobic reaction. The setups were operated at room temperature. The OCV of the three setups were measured using a digital multimeter for two weeks. Samples of the substrates were taken from the anode chamber every two days for microbial analysis. The samples were diluted serially after which they were cultured using pour plate technique. Inoculated petri dishes were incubated at 37^0C for 18-24 hours for bacteria while fungi was incubated at 25^0C for 48-72 hours.

Table 3: Fungal succession during energy generation from poultry droppings

TIME (DAYS)	ISOLATED FUNGI
1	*Aspergillus niger, Aspergillus flavus, Aspergillus fumigatus, Rhizopus stolonifera, Candida* sp., *Saccharomyces* sp.
3	*Aspergillus niger, Aspergillus flavus, Mucor mucedo, Candida* sp., *Saccharomyces* sp.
5	*Mucor mucedo, Aspergillus niger, Candida* sp., *Saccharomyces* sp.
7	*Candida* sp., *Saccharomyces* sp.
9	-
11	-
13	-

3. RESULTS AND DISCUSSION

Figure 1 showed the variation of the OCV for the three setups. The OCV obtained from the MFCs ranged from 0.06 to 0.72 V with an average value of 0.42 V for the C–C; 0.02 to 0.67 V with an average value of 0.26 V for C-Cu and 0.11 to 0.78 V with an average value of 0.39 V for the C-Zn. It was observed that the OCV for setups 2 and 3 (C-Cu, C-Zn electrodes) decreased with increasing number of hours while the OCV of setup 1 (C-C electrodes) increased with increasing number of hours.

The low output from the C-Cu and C-Zn electrode configurations could be due to bio-incompatibility of the Cu and Zn electrodes with the microbes in the cathode chamber. Table 1 gave the result of the total microbial count in the cow dungs while tables 2 and 3 listed the respective bacteria and fungi isolated from the cow dung substrate. It was observed that the decrease in the microbial load (table 2) had an inverse effect on the output of the OCV measured from the C-C electrode configuration which gave the best output. This could be as a result of the decrease in microbial effects giving rise to internal losses in the system [8].

In literature, some microorganisms such as *Shewanella* sp, *Bacillus megaterium*, *Geobacter sulfurreducens*, *Rhodoferax ferrireducens* etc., had been identified as being eletrogenic [1,6,10]. From Table 3, it could be seen that some other microorganisms which has not been identified as being electrogenic were isolated. There could be a possibility that many microbes possess the characteristic of electricity generation, or there could be a symbiotic relationship between the electrogenic and non-electrogenic microbes that could facilitate the generation and transfer of the electrons generated to the electrodes. The results obtained from the present work was also found to be comparable to results obtained from literature (Table 4).

Table 4: Comparison of the result from the present works with values from literature

Voltage (V)	Reference
0.78 (cow dung)	Present work
0.72 (Cow dung)	Parkash *et al*., [11]
0.71 (Cow dung)	Kumar *et al*., [12]
0.14 (Soil)	Intaravicha and Changjan, [13]
0.61 (*E.coli*)	Xi and Sun, [14]
1.65 (Sewage)	Chaithanya *et al*., [15]

4. CONCLUSION

The effect of electrodes on the voltage generation of microbial fuel cell using cow dung as an organic substrate showed that the carbon electrodes on the anode and cathode chambers gave the best output for open circuit voltage.

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