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THE EFFECT OF ELECTRODES ON THE VOLTAGE GENERATION OF MICROBIAL FUEL CELL

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Abstract

Energy is a necessity for life to thrive on earth. Human has majorly acquired energy needed through the use of fossil fuel which had proven to be efficient and economical. The only drawback to the use of fossil fuel is the emission of greenhouse gases during its combustion. Also, in the recent times, population and economic growth has led to huge increase in energy demand and consumption worldwide. Thus, there is need to develop and improve on the efficiency of technologies that would produce less-carbon intensive energy sources that would serve as alternatives to the present day carbon intensive energy sources. 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. Three sets of MFCs using poultry droppings as organic substrate, were constructed to study the effects of electrodes on the voltage generation of MFC. The anode and cathode compartments were connected using a proton exchange membrane and the poultry droppings of 1 kg diluted with 500 ml of water was introduced in the anode compartment of each of the setups. Carbon-Carbon(C-C), carbon-copper(C-Cu) and carbon-zinc(C-Zn) electrode combinations for the anode–cathode were used for set-up 1, 2 and 3, respectively. Samples for microbial load count were collected every two days from the anode compartment of the MFC and analyzed using standard microbiological methods. The open circuit voltage (OCV) of the three setups were measured daily for two weeks. The microbial load ranged from 3.4×10^4 to 1.6×10^4 CFU/ml for bacteria and 0.6×10^3 to 3.3×10^3 CFU/ml for fungi. The OCV obtained ranged from 0.19 to 0.71 V, 0.21 to 0.38 V and 0.18 to 0.52 V for set-up 1, 2 and 3, respectively. The OCV for the setup with C-C electrode combination increased while that of the C-Cu decreased with increasing number of days but there were fluctuations in the OCV of the C-Zn electrode. The C-C electrode combination gave the best OCV.

1. Introduction

Energy is a major factor for the survival and growth of living things on earth[1, 2]. During the last century, population growth and economic development has led to increased demand and consumption of energy. And as the global population keeps increasing and more countries are developing, there will be increased pressure on energy demand[3]. Energy demand has been projected to grow by more than 50 % by 2025 [4]. Current energy consumption is basically acquired from fossil fuel because it has proved to be the most economic and efficient source of energy [5]. The major drawback of fossil fuel is its contribution of huge percentage of the greenhouse gases that accumulate in the atmosphere and lead to the global temperature rise with adverse effect on humans and the planet[6, 7]. Thus, there is need to develop cleaner and less-carbon intensive technologies that would serve as alternatives to the present energy sources. Bioenergy sources are regarded as one of the renewable and sustainable means of alleviating the energy crises as well as maintaining a cleaner environment [5].

Microbial fuel cell (MFC) is a device that converts the chemical energy of an organic substrate into electrical energy through the catalytic actions of microorganisms [8, 9, 10, 11]. It is typically made up of an anode and a cathode chamber. The organic

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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 [12]. 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 [13, 14]. 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[12, 13].
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 [15]. In this work, the effect of different electrodes on the open circuit voltage (OCV) of mediator-less, dual chambered MFC with poultry droppings 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 container search 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. 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 poultry droppings and 500 ml water. 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. 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 chamber while set-up 3 was connected with carbon electrode in the anode chamber and copper electrode in the cathode chamber. The diameters and lengths of the electrodes were 1.5 cm and 15.3 cm, 0.5 cm and 13.2 cm. and 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 the anaerobic reaction. The setups were place and 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.

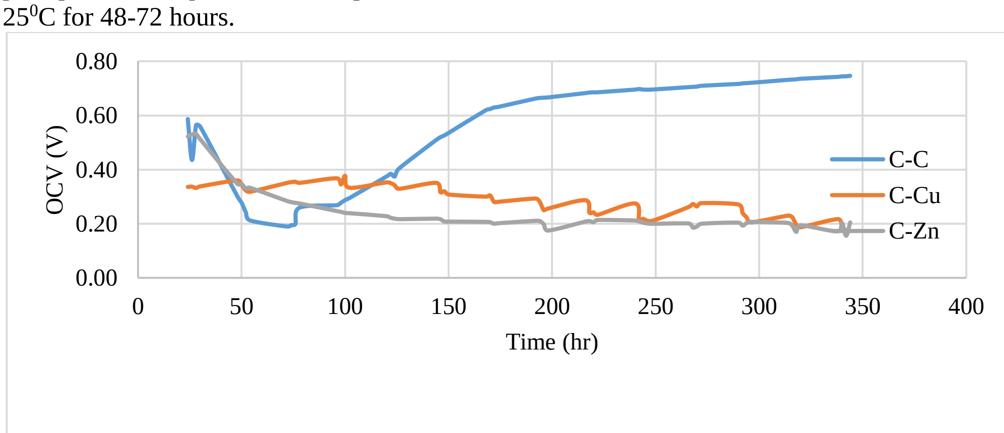

Figure 1: Open circuit voltages for the different electrode configurations

1. Results and Discussion

The OCV obtained from the MFCs ranged from 0.19 to 0.71 V, 0.21 to 0.38 V and 0.18 to 0.52 V for set-up 1, 2 and 3, respectively. Figure 1 showed the variation of the OCV for the three setups. Table 1 gave the result of the total microbial count in the poultry droppings while tables 2 and 3 listed the respective bacteria and fungi isolated from the substrate. 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 C-C electrode configuration gave the best OCV output. This observation is in line with literature as carbon electrodes have proved to be biocompatible with the microorganisms in the substrates (Santoro *et al* 2017). 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. It was also observed that the decrease in the microbial load (table 2) had an inverse effect in the OCV measured from the C-C electrode configuration that gave the best output. This could be as a result of the decrease in microbial effects giving rise to internal losses in the system [13]. In literature, some microorganisms had been identified as being eletrogenic. From table 3, it could be seen that some other microorganisms which had not been identified as being eletrogenic wereisolated. There could be a possibility that many microbes possess the characteristic of electricity generation, or there could be a symbiotic relationship between the eletrogenic and non-electrogenic microbes that could facilitate the generation and transfer of the electrodes generated to the electrode. The results obtained from the present work was also found to be comparable to results obtained from literature (table 4).

Table 1: Total Microbial Count of poultry droppings

TIME (DAYS)	BACTERIAL LOAD (CFU/ML)	FUNGAL LOAD (SFU/ML)
1	8.8 X 10^4	3.3 X 10^3
3	3.2 X 10^5	3.0 X 10^3
5	1.6 X 10^5	2.0 X 10^3
7	7.6 X 10^4	0.6 X 10^3
9	4.1 X 10^4	-
11	4.0 X 10^4	-
13	3.4 X 10^4	-

Table 2: Bacterial succession during energy generation from poultry droppings

TIME (DAYS)	ISOLATED BACTERIA
1	*Listeria monocytogenes, Salmonella typhimurium, Micrococcus luteus, Enterobacter cloacae, Bacillus licheniformis, Escherichia coli, Pseudomonas aeruginosa*
3	*Streptococcus* sp., *Salmonella typhimurium, Micrococcus luteus, Enterobacter cloacae, Bacillus licheniformis, Escherichia coli, Pseudomonas aeruginosa*
5	*Enterobacter cloacae, Bacillus licheniformis, Escherichia coli, Listeria monocytogenes, Salmonella typhimurium*
7	*Enterobacter cloacae, Bacillus licheniformis, Escherichia coli, Listeria monocytogenes, Salmonella typhimurium*
9	*Listeria monocytogenes, Salmonella typhimurium, , Escherichia coli, Enterobacter cloacae*
11	*Listeria monocytogenes, Escherichia coli, Bacillus licheniformis*
13	*Bacillus licheniformis, Listeria monocytogenes*

Table 3: Fungal succession during energy generation from poultry droppings

TIME (DAYS)	ISOLATED FUNGI
1	*Penicillium notatum, Aspergillus niger, Fusarium* sp.
3	*Penicillium notatum, Aspergillus niger, Fusarium* sp., *Alternaria* sp.
5	*Penicillium notatum, Aspergillus niger,*
7	*Penicillium notatum, Aspergillus niger*
9	-
11	-
13	-

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

Voltage (V)	Reference
0.71 (Poultry droppings)	Present work
0.72 (Cow dung)	[16]
0.71 (Cow dung)	[17]
0.14 (Soil)	[18]
0.61 (*E.coli*)	[19]
1.65 (Sewage)	[20]

2. Conclusion

The effect of electrodes on the open circuit voltage generation of microbial fuel cell using poultry droppings as organic substrate showed that the carbon-carbon electrodes configuration gave the best output than either carbon-copper or carbon-zinc electrode configurations.

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