Indian Journal of Science and Technology, *Vol 9(30), DOI: 10.17485/ijst/2016/v9i30/99177, August 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Comparison of the Output Voltage Characteristics Pattern for Sewage Sludge, Kitchen Waste and Cow Dung in Single Chamber Single Electrode Microbial Fuel Cell

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Abstract

Background/Objectives: The demand of energy isincreasing exponentially worldwide. This demand is mostly supplied by the fossil fuels, which is a nonrenewable source of energy. The most recently, renewable source of energy, Microbial Fuel Cell (MFC) is attracting the scientist over the globe for research. **Methods/Statistical Analysis**: MFC is a promising green technology which simultaneously generates direct electricity through metabolic activities of the microbes and also treating the organic waste. This technology is not commercialized yet, but holds a promising future, both in terms of energy production and waste reduction. In the present work, a Single chamber single electrode Microbial Fuel Cell (MFC) has been fabricated to generate electricity from sewage sludge, cow dung and kitchen waste at an ambient temperature of 32±10°C. The performance on the basis of voltage obtained, surface power density and COD reduction have been evaluate for those different substrate on same ambient condition. **Findings:** The change in pH is also recorded for all the substrate used. The maximum voltage output of 1652 mV is obtained with sewage sludge on the 5th day (120 hrs.) with the surface power density of 988.32 mW/m^2. The maximum voltage obtained from kitchen waste is about 657 mV on 8th day (192hrs.) and in case of cow-dung the maximum voltage is about 452 mV on 8th day (216hrs.). Almost constant output voltage of about 350 mV for a month can be harvested with cow dung. At the end of the 29th day, the maximum COD reduction for the cow dung was 50%. **Applications/Improvements:** When comparing with other single chamber single electrode MFC, the present model is generating more electricity that any MFC using sewage sludge as substrate except platinum electrode, which is much costlier that electrode used in the present study.

Keywords: Graphite Electrode, Microbial Fuel Cell, Used Dry Cell Voltage

1. Introduction

The Microbial Fuel Cell (MFC) is a promising green technology which simultaneously generates direct electricity through metabolic activities of the microbes and also treating the organic waste. Microorganisms oxidize organic matters aerobically or anaerobically generating electrons and protons. The generated electrons are transferred from the anode to the cathode through an external circuit[1]. This MFC technology is also being used as biosensor and for the generating bio-hydrogen[2,3]. The performance of MFC is mainly depends upon various factors such as electrode materials, substrate and its concentration and microbe, pH, temperature and ionic strength of the substrate. The microbial fuel cells are operated successfully with electrodes such as Platinum, Graphite, Fine woven graphite felt, Carbon woven graphite felt, Carbon paper, Reticulated Vitreous Carbon (RVS). Both pure compounds such as glycerol, acetate, starch, glucose, cysteine, and ethanol[4] as well as complex organic

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matter such as wastewater[5], cow dung[6], kitchen waste[7] is successfully used as a substrate in MFCs. There are several microorganisms that possess the ability to transfer the electrons obtained from the metabolism of organic matters to the anode through biofilm formation. Some of the microorganism which has been studied in MFC are Shewanella putrefaciens, Geobacteraceae sulferreducens, Geobacter metallireducens and Rhodoferax-ferrireducens[8]. There are number of ways in which MFC can be constructed but all these can be broadly classified into two types. Dual Chamber MFC, consisting of two chamber containing anode and cathode, separated by Proton Exchange Membrane (PEM) or sometime salt bridge. Single chamber MFC consisting of a single chamber containing anode without any aerated cathode chamber. The anode chamber is coupled to a porous air-cathode exposed directly to the air. The Single Chamber MFC is cheaper and simple in design than that of dual Chamber MFC. The H shaped traditional dual chamber is bulky due to two separate anodic and cathodic chambers. From India, the maximum potential difference of 423 mV was recorded from wastewater with the COD removal 62.5% at ambient temperature of 28±2°C using double chamber MFC[9,10]. In case of cow dung and composite canteen food waste using double chamber MFC the maximum potential difference of 320 mV and 398 was reported from India. The COD removal data corresponding to the potential difference are not reported. In our present studies for the first time, we have modified the conventional single chamber MFC such way that same electrode can be used as anode and cathode (Figure 1(a)). In conventional single chamber MFC in which anode and cathode are completely different material in design and composition. In our MFC the part of the electrode which is exposed to air acts like cathode which is connected with anode through external circuit. The substrates used are domestic sewage sludge, kitchen waste and cow dung.

2. Materials and Methodology

2.1 Collection of Sample

The sewage sludge is collected from the waste water treatment plant and the kitchen waste is collected from the hostel mess at VIT, University, Vellore campus. The cow-dung was collected from the dairy opposite to VIT, University, Vellore campus. The physiochemical characteristics of the substrates used in MFC are shown in the Table 1.

Table 1. Physiochemical characteristics of sewage sludge, kitchen waste and cow dung

Sl. No.	Parameters	Sewage Sludge	Kitchen waste	Cow Dung
1	COD	80000 mg/l	60000 mg/l	32000 mg/l
2	% of Total Solid	17.2	16.4	15.75
3	% of Volatile Solid	11.6	12.1	11.3
5	Colour	Grey	Pale Yellow	Brown
6	pH	5.3	6.8	7.1

2.2 Fabrication

Three set of MFC of similar type were fabricated for each type of substrate (sewage sludge, kitchen waste, and cow dung). Each type of MFC consists of six substrate chamber which contain 180 ml of substrate with electrode fixed in it and shown in Figure 1(c). Each graphite electrode are connected externally in series with copper wire have been used in this present study. The electrodes are partially submerged in the substrate and partially exposed to atmosphere acting as anode and cathode respectively. About 70% of the total lengths of the electrode were in the sludge and the rest 30% of the length was exposed to the air. The graphite electrodes having 10 mm diameter and 57 mm length were extracted from the used dry cell, before using the electrodes were cleaned with 0.1 M HCl and stored in distilled water for 12 hours. The 70% of the length (40 mm) is anode and 17 mm as cathode, hence the surface area of an anode is 1256 mm^2. The copper wires used for connecting the electrode had the resistance of 0.7 ohms. These six electrodes were fixed in the plastic containers with copper wires and are connected in series externally. The collected substrates were mixed uniformly and was poured into the container and allowed the bacteria present in it to grow and start the metabolic activities in aerobic condition.

2.3 Performance Evaluation Criteria

The three sets of the MFC operated in sewage sludge, kitchen waste and cow dung have been evaluated for maximum voltage output at ambient temperature range of 32±10°C. The voltage output were recorded by the Calibrated multimeter (Model No. MAS83OL) for all the three SETs across the resistor of 1000 ohm at the regular interval of 8 hrs till the output voltage and diminished to zero (least count of the multimeter is 0.01 mV). The surface power density P (mW/m^2) is calculated as P = V^2/(R×A×1000), where V (mV) is the measured fuel cell voltage, R(ohm) external resistant and A (m^2) projected surface area of the anode 1000 is needed for maintaining the units. Apart from the voltage measurement the change of pH of each substrate in MFC was also monitored during the study. The experiment is continued till substantial amount of electricity is generated and after that period the available COD of the substrate is measured to identify the reduction of COD.

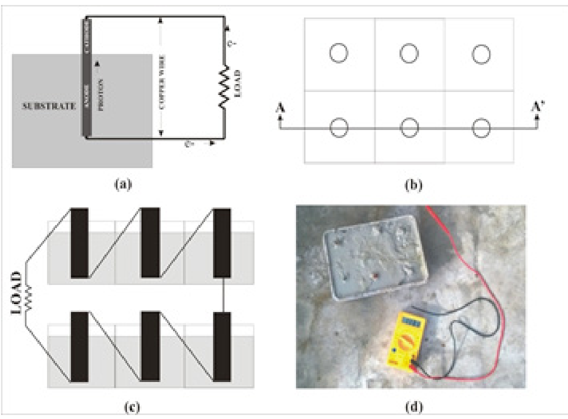

Figure 1. Single chamber single electrode MFC. (a) Circuit diagram of single cell of single chamber single electrode MFC. (b) Schematic representation top view of the setup. (c) Schematic representation of the circuit diagram of single chamber single electrodes MFC in series. (d) Photograph of the experimental setup of the combination of single chamber single electrode.

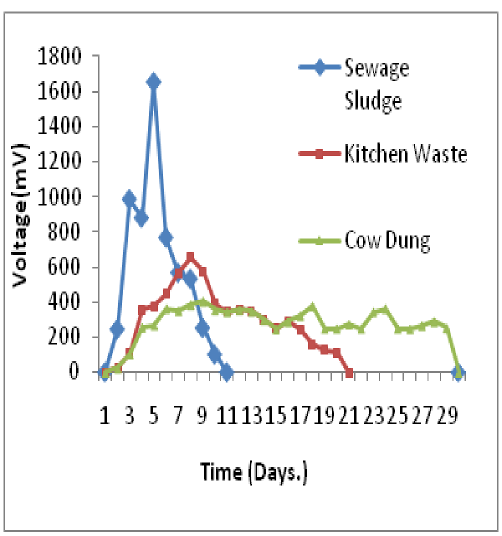

Figure 2. Voltage output for sewage sludge, kitchen waste and cow-dung at 32±10°C.

3. Results and Discussion

3.1 Sewage Sludge

The MFC using sewage sludge has the maximum voltage output of 1652 mV which would achieve on 5th day (120 hrs.). The generation of electricity was substantially slowed down after 11 days (Figure 2). The pH was increased from 5.3 at first day to 6.0 at eleventh day. The overall COD removal was from 80000 mg/L to 56000 mg/L (Figure 3).

3.2 Kitchen Waste

The MFC using kitchen waste has the maximum voltage output of 657 mV which would achieve on 8th day (192 hrs.). The generation of electricity was substantially slowed down after 21 days (Figure 2). The pH was decreased from 7.1 to 5.4 at the end of the experiment. The overall COD removal was from 60000 mg/L to 45000 mg/L (Figure 3).

3.3 Cow Dung

The MFC using cow dung has the maximum voltage output of 452 mV which would achieve on 9th day (216 hour). The generation of electricity was continued for almost one month (Figure 2). The pH was increased from 6.8 at first day to 8.3 at the end of the study. The overall COD removal was from 32000 mg/L to 16000 mg/L (Figure 3).

From the result it is evident that the sewage sludge gives the highest voltage output compared to all the three substrates operated under same ambient condition in our fabricated MFC model. The change of voltage for this substrate is much intense than other substrates and the generation of electricity almost stopped after 11 days, which is much shorter compared to cow dung, i.e., almost one month. The MFC which used cow dung as substrate generate lowest electricity among the three but it was very much stable compared to the other.

Reduction of COD was highest in cow dung which is around 50% compared to 30% and 25% for sewage sludge and kitchen waste (Figure 3).

4. Conclusions

The highest surface power density found to be 988.3 mW/m^2 from sewage sludge. This value when compared

Table 2. Comparison of the present study results (the maximum voltage and/or power density) with the reported results.

Substrate	Electrode	Voltage	Power density	Refs.
Sewage sludge	Graphite	NA	152 mW/m^2	10
	Platinum, polyanilineco-modified	NA	6000 mW/m^2	10
Present study	Graphite	1652 mV	988.3 mW/m^2	
Kitchen waste	Graphite	398 mV	NA	7
Present study	Graphite	657 mV	57.27 mW/m^2	
Cow dung	Graphite	320 mV	NA	6
Present study	Graphite	452 mV	27.11 mW/m^2	

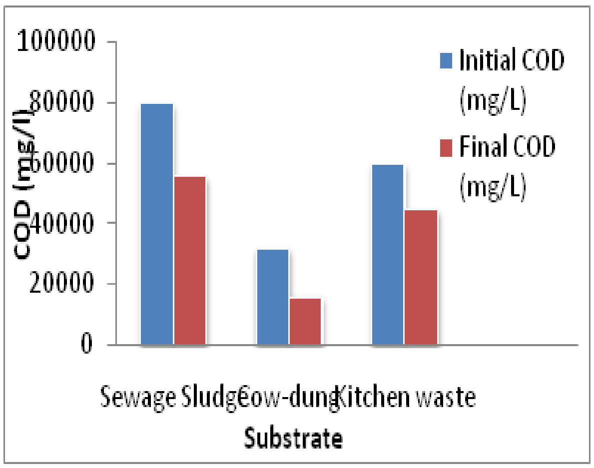

Figure 3. The COD reduction for sewage sludge cow-dung and kitchen waste and cow-dung.

with any other reported study on MFC which used sewage sludge as substrate was found to be very encouraging (Table 2). The maximum peak voltage is also obtained in lesser days than that of kitchen waste and cow dung. Thus, the most suitable candidate for production of electricity using microbial fuel cell is the sewage sludge but the digestion period is low. There is problem of change in polarity. For the food waste the peak is higher than cow-dung but again here there is problem of polarity change. In case of cow-dung there is almost constant power output but the peak is not very high it could be increase by adding some mediators.

When the reduction of COD level in all the substrate was compared against the maximum voltage output produced, it has been found that the sewage sludge most efficiently produce electricity from the substrate, i.e., 63.7 mV/gm COD reduction compared to 40.6 mV/gm COD reduction and 26.16 mV/gm COD reduction for kitchen waste and cow dung respectively, though COD reduction was highest in cow dung. That indicates the reduction of COD for cow dung was not mostly contributing to the generation of electricity. On the other hand the decrease of pH for the kitchen waste indicates high proton-transfer resistance in that MFC. This is a very preliminary study for the performance of electricity generation through our developed MFC. The result is very encouraging though more details study is required to understand and optimize various designing parameters which is ongoing stage.

5. Acknowledgement

We are very grateful to Vellore Institute of Technology for the financial support to carry out the above project work.

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