



## Short communication

## Bioelectricity generation from different biomass feed at anode chamber and to study process parameters in microbial fuel cells

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## ABSTRACT

The present study involves the effect of different bio-wastes on voltage production in a laboratory scale fabricated microbial fuel cell (MFC). Bio-wastes such as cow-dung, sludge and soil mixture were used at the anodic chamber. The voltage generated by MFC was studied as a function of different parameters like temperature, time, pH and percentage of organic matter. Different salts (Sodium chloride, Sodium bicarbonate, Sodium carbonate) and their concentration were varied at the salt bridge. Experimental results showed that the presence of percentage organic matter in cow dung along with drain water was 0.85 and the same generated 230 mV of voltage. The voltage output of 223 mV and 215 mV were drawn with the effect of time and temperature respectively by the same composition. In addition, pH 8 with 1M Na<sub>2</sub>CO<sub>3</sub> salt concentration produced 330 mV of voltage. The obtained results suggest that this fabricated MFC can further be studied for electrochemical evaluation for the generation of electricity in the process of wastewater treatment.

## 1. Introduction

The extensive use of fossil fuels and carbon resources has left environmental pollution at an alarming level. The production of energy through available resources has shown a direct impact on climate change. Hydrogen as a fuel has gained great attention in recent years. More interestingly microbial fuel cell (MFC) had appeared to be more environment-friendly for electricity generation (Chandra et al., 2019; Venkata Mohan et al., 2008). These are biochemical catalyzed systems. They enable microbes for the conversion of chemical energy into electrical energy produced by the oxidation of inorganic or organic compounds found in wastewater (Amit and Ghosh, 2018; Xie, 2015). MFC can be considered an alternate renewable energy source. It generates electricity from waste which is abundant and cheapest input to the system. The motivating principle involved in MFCs is that they produce electricity by microbial activity of bacteria. The studies related to the advancement of bio-electricity generation, microbial physiology, and its kinetics have gained momentum in developing this technology (Nayak et al., 2018). When compared to other fuel cell technologies, mild reaction conditions, energy conversion efficiency, and eco-friendly are counted as advantages of MFCs. They also possess many benefits including both functional and operational based on energy production in the handling of waste streams (Logan, 2008).

MFC consists of two chambers where oxidation and reduction

reactions take place at anode and cathode respectively. Both of them are connected through the proton exchange membrane or salt-bridge. Microbes oxidize organic matter present in the anodic chamber to produce water and carbon dioxide (CO<sub>2</sub>) in the presence of oxygen. If the same reaction happens to occur in the anaerobic environment, then organic matter gets decomposed to produce CO<sub>2</sub>, electrons, and protons. These negatively charged particles are transferred to the cathode chamber over an external circuit generating voltage whereas protons via a salt bridge (Parkash, 2015). In general, mediator-less MFCs are widely used and the bacteria (electrogens) are electrochemically active to transfer the electrons to the electrode (Mahendra and Mahavarkar, 2013). According to Du and his co-authors (Du et al., 2007), these bacteria can be found in a number of places such as freshwater sediment, marine sediment, soil, activated sludge, wastewater etc. The present study involves laboratory setup of mediator-less MFC where cow dung and drain water are used as substrates for the anodic chamber. An attempt had been made to study the influence of various parameters such as time, temperature, the composition of wastes and salts on the performance of an MFC in the present work.

## 2. Experimental setup

A two-chambered MFC was fabricated at a laboratory scale. The substrate materials such as cow dung compost, municipal sludge with

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Fig. 1. MFC system setup at the laboratory scale.

drain water were collected from the campus area (National Institute of Technology, Rourkela). Two separate plastic containers of 4l capacity were used for anode and cathode chambers. Anode container was filled with cow dung compost and drain water sludge. Aforesaid headspace was purged by pure nitrogen gas at the rate of  $2.0 \text{ l min}^{-1}$  to maintain anaerobic atmosphere before starting the experiment for about 15min. Cathode was filled with water and aeration pump was attached for oxygenating purpose. Graphite electrodes and aeration pump were inserted through drilled holes on the lid surface of anode and cathode chambers respectively. 1.5 kg of cow dung was mixed to 3l of drain water for cow dung-drain water mixture sample. The cow dung was diluted with distilled water at 1:1 ratio for cow dung sample. 3l of drain water was used for a drain water sample. The salt bridge was prepared by heating 1M salt solution along with agar to achieve uniformity. The cotton rope of approximately 30 cm was dipped in the above solution. The concentrated dense rope was frozen for solidification. This solidified rope (salt bridge) was placed in between the plastic containers as shown in (Fig. 1). Electrodes ends were connected to a digital multimeter (EEE-Tech, MAS-830L) to measure the voltage produced by the microbial activity of the microbes. To study temperature effect on the microbial activity of bacteria, two experimental setups were engaged with different temperatures. One at a temperature of 20–25 °C and other at 30–35 °C. To maintain the temperature at 20–25 °C, the entire setup was kept under cooling-bath circulated with cold water. A temperature probe was used to regulate low temperature as these experiments were carried out in summer where room temperature persisted above 25 °C. In the other case, the temperature was maintained from 30 to 35 °C using room heater to maintain the required warm conditions.

### 3. Results and discussions

#### 3.1. Effect of organic matter on voltage yield

The voltage generated with the influence of organic matter present in substrates (drain water, cow dung, and cow dung-drain water mixture) was studied. Amount of organic matter was calculated by the standard procedure of total organic carbon analyzer (Shimadzu, TOC-VCPN). It was observed that more organic matter is present in cow dung with drain water mixture sample than compared to the individual sample. The organic matter (%) present in the anode chamber decreased gradually by increasing the operating time period up to 12 days. Microbes grow exponentially and reach a point where the nutritious atmosphere will begin to deteriorate. Therefore the organic matter experiences depletion. It might be due to the absence of nutrition supply to substrates. Voltage production by MFC increases with the increase in the amount of organic matter as shown in (Fig. 2) & (Fig. 3 (a)).

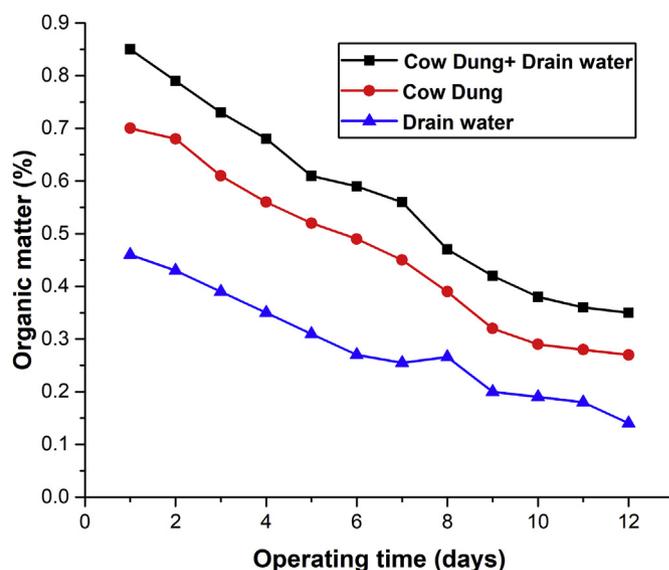


Fig. 2. Plot showing the effect of time on the organic matter (%) present in substrates.

#### 3.2. Effect of time elapsed(days) on voltage production

All the samples were kept under observation for eight days. The potential difference was measured by a multimeter. Effect of time on the voltage output of the MFC is shown in (Fig. 3 (b)). Voltage output directly depends on the rate at which microbes grow. This growth rate is divided into four stages. The time taken by the microbial activity to reach each phase as well as the amount of time they spend in each phase depends on many factors such as temperature, microorganisms, and nutrients supplied. Therefore, the voltage produced and microbial growth rate will differ from these factors accordingly (Muler, 2015).

#### 3.3. Effect of temperature on voltage production

We have observed that a combination of cow dung with drain water has yielded better results. The temperature effect had been studied with the same sample at anode. The microbial activity depends on temperature, as the bacteria present in these samples are mesophilic. In general, this kind of bacteria exhibits good metabolic performance in the temperature range of 30–45 °C. (Fig. 3 (c)) shows that the voltage produced is high for the experiments conducted at 30–35 °C than 20–25 °C. It might be due to higher rates of microbial activity of microorganisms which is in accordance with the literature (Hong et al., 2009). The graph pattern shows that the performance of cell decreases with increase in temperature.

Temperature affects the microbial mass and its activity at the anode. The system temperature should be maintained at stable in the range of 25–40 °C at operating conditions. The electrochemically active microbes get adversely affected by the increase in temperature (Song et al., 2017). Therefore, we can say that temperature accounts as an influential parameter in MFCs.

#### 3.4. Effect of pH and concentration of salts on voltage generation

The effect of pH on voltage generation was studied by using different salts at the salt bridge. Variation of voltage with pH for all substrates is shown as in (Fig. 3 (d)). Cow dung with drain water at pH 8 had produced better results in voltage output of 220 mV. NaCl,  $\text{Na}_2\text{CO}_3$ , and  $\text{NaHCO}_3$  were selected to study the effect of salts based on the optimized pH value. Salt bridge in MFCs plays an active role in transferring protons through it to cathode chamber by dissociating ions in it. It was observed that the voltage generation was maximum for

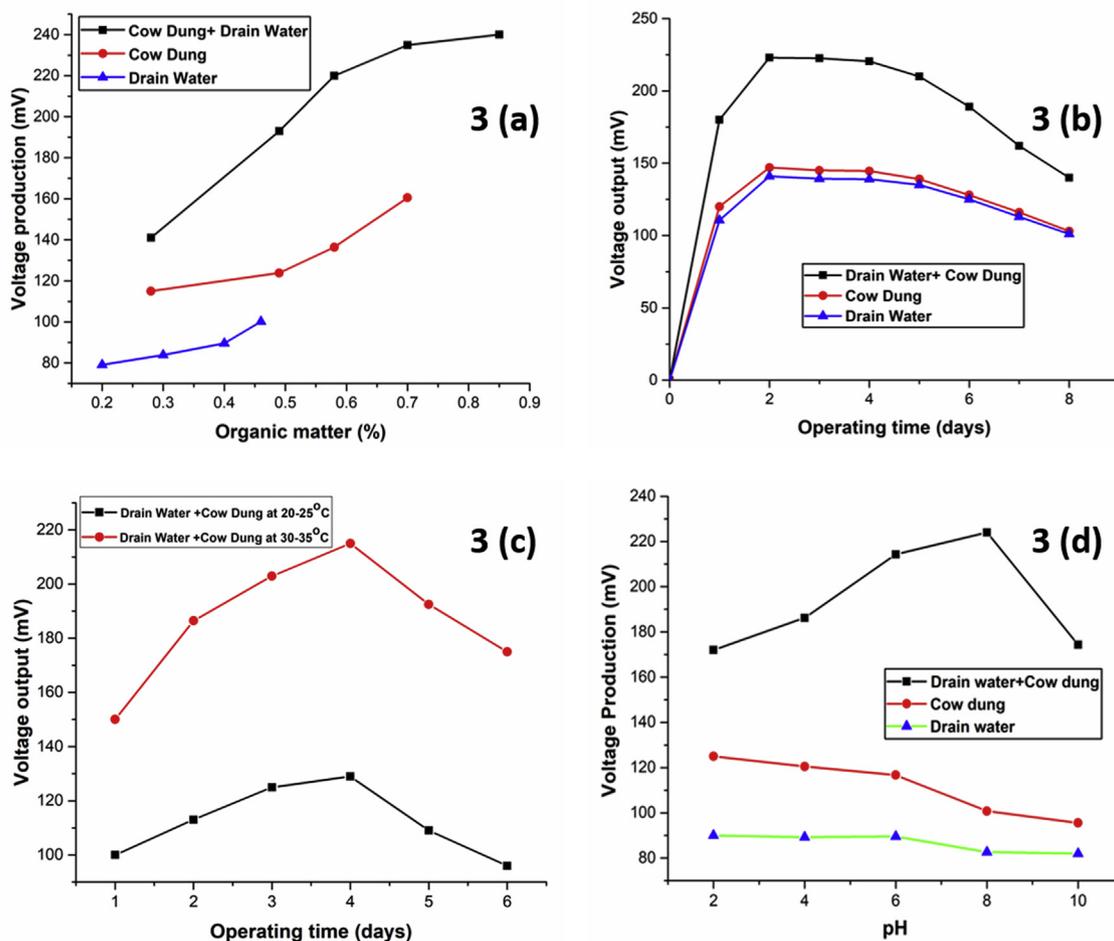


Fig. 3. (a). Effect of organic matter (%) on the voltage production, (b) Plot between operating time (days) vs voltage production, (c) Plot showing the effect of temperature on voltage output, (d) Plot between pH vs voltage production.

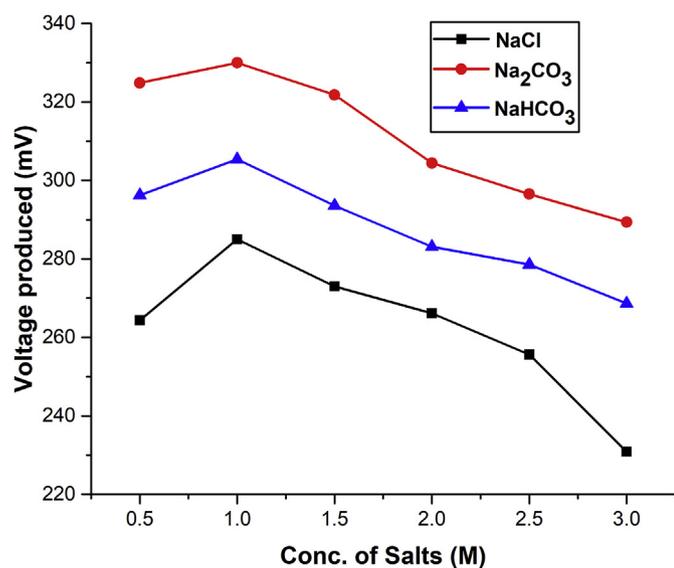


Fig. 4. Effect of concentration of salts on voltage production for drain water + cow dung mixture.

Na<sub>2</sub>CO<sub>3</sub> compared to NaCl and NaHCO<sub>3</sub> for cow dung with drain water mixture as shown in (Fig. 4). The graph patterns exhibit that the molar concentrations of salts influenced the voltage produced. It develops the understanding that higher concentrations lead to a decrease in voltage

output (Prakash et al., 2015). Among other salts, optimum results were attained by 1M Na<sub>2</sub>CO<sub>3</sub> which generated a maximum voltage of 330 mV.

#### 4. Conclusion

The electrical output of an MFC is greatly affected by the type of substrate used at the anodic chamber. From the experimental results, it can be understood that the cow dung along with drain water mixture sample contains a higher percentage of organic matter and therefore drawn the maximum voltage output of 240 mV. Parameters such as operating time (days) and temperature also showed a significant effect on voltage production. Maximum of 223 mV of voltage was generated on the second day and continued up to 220 mV till the fourth day and gradually decreased. The temperature of 30–35 °C favored the better voltage production of 215 mV. Alkalinity (pH of 8) favored the increase in organic matter thereby affecting the performance of the MFC. Variation in salt concentrations also made a substantial impact on the performance of salt bridge in disassociation of ions. 1M Na<sub>2</sub>CO<sub>3</sub> was found to produce a high voltage output of 330 mV. As per the results obtained, the present fabricated cell appears to be suitable for electrochemical characterization.

#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.bcab.2019.101191>.

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