Evaluation of Open Circuit Voltages of Microbial Fuel Cells from Cow and Pig Dungs

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ORIGINAL RESEARCH

Abstract- A microbial fuel cell (MFC) has many potential applications, including wastewater treatment, environmental monitoring and bioenergy production. The comparison of the open circuit voltages OCV values for three MFC set-ups using cow dung, pig dung and the combination of cow and pig dungs was carried out in this study. The MFC fabricated locally consist of two chambers – the anode, which is an anaerobic digestion of organic waste with an electrode on top of the digester lid while potassium permanganate was mixed with water in a chamber to form the cathode with an electrode on top of the lid. The two chambers were linked with a proton exchange membrane (PEM) made with agarose agar using PVC pipe. For 30 days, the OCV of the MFC set-ups were recorded. The OCV values for the three set-ups were compared. According to the results, the average OCV values for cow dung, pig dung, and a mixture of both are 1.014 V, 0.610 V and 0.430 V, respectively. This shows that cow dung produced the highest OCV values, followed by pig dung. The OCV values from the mixture of both had the lowest results.

Keywords- Cathode and anode, cow dung, pig dung, open circuit voltage, proton exchange membrane

1 INTRODUCTION

Harnessing bioenergy from organic waste through microbial fuel cells (MFCs) represents an innovative technology with the capacity to tackle two pressing challenges: efficient waste management and sustainable energy generation. The contemporary global landscape is confronted with an acute energy crisis, exacerbated by an unsustainable surge in energy demand. In response to this predicament, there is a growing spotlight on renewable energy derived from organic waste as a viable and eco-friendly substitute for conventional fossil fuels (Kuang *et al.*, 2016; Olaniyan and Ajayi, 2021).

Organic waste, such as food waste, agricultural waste, animal dung and municipal solid waste, represents a significant untapped source of energy that can be converted into renewable energy through processes of a bio-electrochemical system (i.e. MFC). Recently, MFCs have drawn increasing worldwide attention in generating electricity directly from organic matter (Logan and Elimelech, 2012). Microbial fuel cells (MFCs) are a promising technology for generating renewable energy from organic matter due to their advantages (Bhatia *et al.*, 2023). However, MFC is a bio-electrochemical system that produces electricity by harnessing the metabolic activity of microorganisms, such as bacteria or algae (Choi and Ahn, 2013; Parkash, 2016).

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Section B- ELECTRICAL/COMPUTER ENGINEERING & COMPUTING SCIENCES
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The essential components of MFC include an anode, cathode, proton/ion exchange membrane, substrate and electrode catalyst (Allen and Bennetto, 2007; Tender. *et al*.., 2008; Winfield. *et al*.., 2006). In an MFC, these microorganisms break down organic matter in the anode chamber, releasing electrons that flow through an external circuit to the cathode chamber, where they combine with oxygen to form water (Sandeep, 2015). The movement of these electrons generates an electrical current that can be harnessed to power devices or to store energy in batteries, as represented in Figure 1 (Aelterman *et al*., 2016).

In MFC, any form of organic matter, including chocolate, wine, wastewater, acetate, glucose, and dung from various animals, can be used as a substrate (Srivastava *et al*.., 2022). Most MFCs use platinum as the catalyst, which is extremely expensive. Due to the high cost of platinum, which affects the viability of fuel cells, most researchers opt for cheaper options such as ferricyanide and potassium permanganate, which have been used successfully with results comparable to those achieved with platinum (Chaturvedi and Verma, 2016).

Much of the research performed on the monitoring of OCV values for MFCs using cow dung (Parkash *et al.*, 2015; Siddique *et al.*, 2018; Kumar *et al.*, 2012; Navinraja *et al.*, 2015) and pig dung (Adegunloye and Faloni, 2020; Estrada-Arriaga *et al.*, 2017) have considered the wastes separately. Some monitored the OCV values for a few minutes or days (Siddique *et al.*, 2018), while others monitored for many days (Adegunloye and Faloni, 2020). This study investigates how mixing pig and cow dungs as a substrate affects the OCV values recorded for 30 days. It is important to note that the main focus of this work is monitoring and comparing the OCV values of three different substrates taken for 30 days, not the chemical reactions of both the anode and the cathode chambers. The substrates used were cow dung only, pig dung only and, cow and pig dungs mixed in equal ratios.

2 METHODOLOGY

A small-scale MFC generation system was designed to generate bio-electricity using two different organic wastes. The electric energy produced was evaluated using a digital multi-meter for 30 days. It is important to note that the electrical properties of MFCs are highly dependent on their bio-electrochemical properties. Like other electrochemical cells, this temperature can influence environmental properties (Prasad and Tripathi, 2022). It should also be noted that the set-up was placed in a location shielded from direct sunlight and heat.

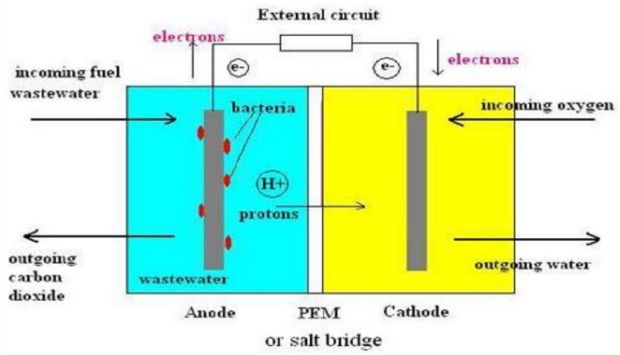

Fig. 1: A general schematic of a microbial fuel cell. (logan, 2006)

2.1 SUBSTRATE

The wastes used as substrates are cow and pig dungs collected from pigsties and cattle pens located at the Power Line Area, Osogbo, Osun State. For this study, three set-ups were developed (cow dung, pig dung and a mixture of cow and pig dungs in equal proportion). Each set-up comprises two chambers, as depicted in the block diagram shown in Figure 2. The anode and cathode chambers exchange protons through the PEM. The anode chamber consists of the slurry and electrode, while the cathode chamber consists of the distilled water, potassium permanganate and electrode.

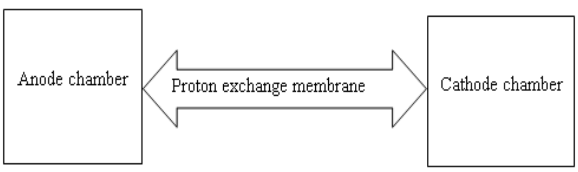

Fig. 2: Block diagram for double chamber MFC

2.2 DESIGN OF ANODE AND CATHODE CHAMBERS

The anode chamber consists of the dung slurry and electrode. The container that was used is a 30-litre keg. The large container produced a higher OCV value than those recorded in related works of Adegunloye and Faloni (2020) and Siddique *et al.* (2018). The dung slurry was made by mixing the dung and water using a 1:1 ratio (i.e. 10 kg of waste and 10 kg of water) according to the modification reported by Parkash *et al.* (2015). The electrode was obtained from the tiger alkaline battery, which is popular in open markets. The tiger battery was dismantled to access the electrode, and the electrode was tightly connected to a conductor. The electrode attached to the conductor was then suspended inside the chamber through the small hole in the keg cover. The suspension was done so that the electrode almost touched the base of the container. The side of the keg was perforated to create a small passage as an outlet to connect the PEM to the cathode chamber. The connection of the PEM must be tightly done to avoid leakage of the slurry and catalyst. The cathode chamber consists of distilled water mixed with potassium permanganate and an electrode (tightly connected to a conductor). Like the anode chamber, the electrode was suspended inside the chamber through the small hole created on the keg lid, as shown in Figure 3.

2.3 DESIGN OF THE PROTON EXCHANGE MEMBRANE

The PEM was made using a salt bridge. To create the salt bridge, 3.51 g and 8 g of sodium chloride (NaCl) and nutrient agar were poured into a conical flask, respectively. Distilled water of 600 ml was also poured into the same conical flask and stirred with a rod. The mixture was then heated to 100 °C on the gas burner to homogenize (dissolve). After homogenization, the dissolved solution was poured into a plastic plate, and stove wool was inserted into the plate. The homogenized solution and the stove wool were then stirred anticlockwise for 20 minutes, after which the stove wool was left in the solution to soak and solidify. A pictorial appearance for each set-up is shown in Figure 3.

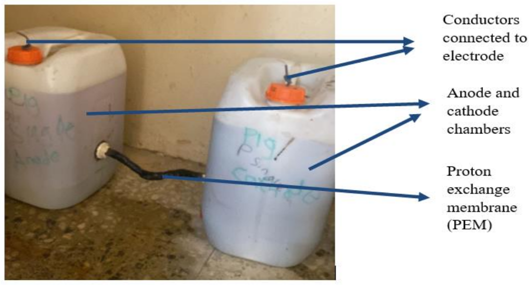

Fig. 3: Image of complete MFC set-up

3 RESULTS AND DISCUSSION

This section presents the results, observation, analysis and evaluation of MFC for electrical energy generation. The open circuit voltage (OCV) readings were recorded for 30 days. A sample OCV reading on one of the set-ups is shown in Figure 4. Figure 5 shows the comparison of the OCV values for the three set-ups. From the Figure, it is clear that cow dung produced the best OCV throughout the study. The OCV for cow dung ranges from 0.86 V to 1.109 V; these values were recorded on days 1 and 19, respectively. The pig dung produced better OCV (when compared to the mixture of pig and cow dungs) from days 1 to 15 and days 24 to 30. The OCV from the pig dung set-up ranges from 0.64 V on day 1 to 0.769 V on day 8. The OCV from the set-up for the mixed dungs ranges from 0.203 V on day 1 to 0.712 V on day 19. It is important to note that the OCV from the mixed wastes showed values that are better for some days when compared to that of pig dung only. However, on an average rating, the OCV values for pig dung were better than the ones recorded for mixed dungs. The daily OCVs recorded from these substrates result from their electrochemical properties. These properties vary for every set-up.

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It should be noted that the study of these properties is not within the scope of this work. The average OCV values for all set-ups for the 30 days are 1.014 V, 0.610 V and 0.430 V for cow dung only, pig dung and a mixture of both, respectively. Generally, the OCV values for all three set-ups were low at the beginning of the monitoring but increased with time. The recorded low voltages initially were because the microorganisms were forming in the slurry (anode chamber). The increased voltages recorded with time indicated that many microorganism activities exist in the slurry (anode). The low voltages recorded after the peak OCV values might be due to the weak metabolic activities of the microbes in the chambers (Navinraja *et al.*, 2015).

Fig. 4: Evaluation of electricity generated from one of the MFC set-ups

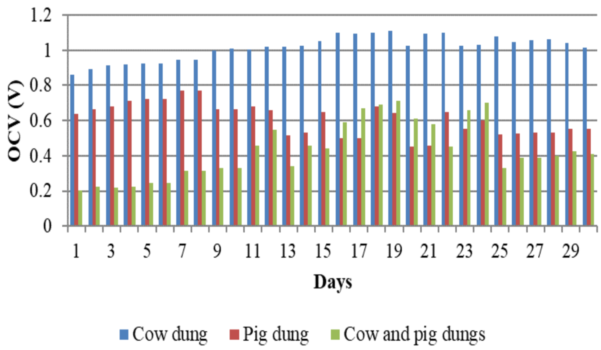

Fig. 5: Comparison of OCV values for the three set-ups

4 Conclusion

From the results obtained, it can be concluded that cow dung produced the highest OCV values throughout the period under study, with a peak OCV of 1.109 V at day 19. The average OCV values also show that the voltage produced by pig only is better than the ones recorded for the mixture of both. It indicates that mixing both doesn't have significant benefits compared to using them singly.

Further works should combine the OCV values of different set-ups of the same substrate to give higher voltages sufficient to produce current that can energize some basic electrical and electronic components.

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