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Production of Bioelectricity Using Single Chamber Microbial Fuel Cell

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Abstract: The present study addressed the application of sandwich-type air cathode microbial fuel cell (ACMFC) for the production of bioelectricity. Activated carbon was pasted on aluminum mesh for the manufacture of anode and cathode. This electrode design eliminated the requirement for carbon cloth or a metal catalyst, resulting in a cathode with excellent activity for oxygen reduction. The findings demonstrated that open circuit voltage (OCV) initially rose with duration due to microbial growth rate. Furthermore, decreases in voltage are seen, probably as a result of a decrease in sufficient feed for the number of microbes. When fed with glucose (substrate), OCV suddenly increased when the bacteria re-grow and then maintains a consistent amount. The current was recorded employing a multimeter, the same as the OCV. The produced current was found to have increased significantly. These results demonstrate that activated carbon is an economical substance for obtaining advantageous oxygen reduction rates in ACMFC.

Keywords: Microbial Fuel Cells, Electrode Materials, Activated Carbon, OCV, Aluminum Mesh

Introduction

Microbial Fuel Cells (MFCs) are bio-electrical systems that employ microbes to transform biological waste into power (Logan *et al*., 2006; Silva-Palacios *et al*., 2023; Eslami *et al*., 2023). However, MFC is too costly to be used for practical applications (Bourdakos, 2012). That is why it is critical to reduce the price of the substances employed in MFC (Du *et al*., 2007). In terms of the most important proportion of overall investment expenditure, the cathode makes the greatest proportion (Rozendal *et al*., 2008). Increased power generation in MFCs is typically limited by cathode surface area and ingredients (Logan *et al*., 2007; Cheng *et al*., 2006a; Huang and Logan, 2008). As a result, identifying inexpensive components and efficient cathode topologies is critical for enhancing the affordability and efficacy of MFCs (Rabaey *et al*., 2005a; Shahi *et al*., 2021).

Ingredients which are primarily employed as electrodes for ACMFC are carbon-based (Aelterman *et al*., 2006). Still, the cost of these carbon-based materials is very high. This precludes their use on a commercial level; while low-cost cathodes have been created by adding metallic coverings to minimal-cost membranes, power densities have been rather low (Zuo *et al*., 2007; 2008; Rabaey *et al*., 2005b). We recently studied a different technique in this study, building the cathode by using aluminum mesh and pasting activated carbon over it on both sides. Coating of catalyst (Pt 0.5 mg/cm^2) over the activated carbon can improve performance, but it is costly. In spite of the high cost of Pt, recent research has demonstrated that Pt loading can be as low as 0.1 mg/cm^2 on an Air Cathode (AC) waterside without affecting power densities (Dumas *et al*., 2007). Co-Tetra Methyl Phenyl Porphyrin (Co TMPP) can be used to replace Pt with little or no effect on MFC performance (Cheng *et al*., 2006b; Zhao *et al*., 2005).

We investigated the usage of an MFC made of simple activated carbon that doesn't need any extra metal catalysts for effective oxygen reduction. We wrapped the activated carbon around an Aluminium (Al) mesh current collector to make scaling up to bigger cathode diameters easier. MFCs built with metal mesh activated carbon cathodes are high-performance, low-cost, and environmentally friendly (Zhang *et al*., 2009; Phung *et al*., 2004). There are four components of the fuel cell: The anode, the cathode, the proton exchange membrane, and the external circuit. An external circuit draws electrons out of the oxidation process as released energy and into the electron acceptor (Nevin *et al*., 2008). The protons move across the ion/proton exchange membrane and react with the electrons in the cathode through the reduction process, completing the circuit. This straightforward

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procedure, which is ubiquitous in most fuel cells, including battery and hydrogen fuel cells, may be optimized for efficient current production. Investigation of distinct substances employed in electrodes that maintain effectiveness with affordability is critical to the prospective large-scale usage of MFC, particularly in wastewater treatment facilities that are planned to be power-generating plants rather than power-consuming plants.

Materials and Methods

A cylindrical box made of plastic was used for making MFC and all the activities took place in this box diameter of 11 cm Fig. 1. An aluminum mesh is used for making cathode and anode. Scissor is used for cutting mesh in a circular shape used as electrodes in MFC. Two small holes were made in the cathode chamber to insert wires. Activated carbon or charcoal is used for making cathode and anode. Anaerobic sludge got from the wastewater treatment plant in Bhagwanpur, Varanasi, India.

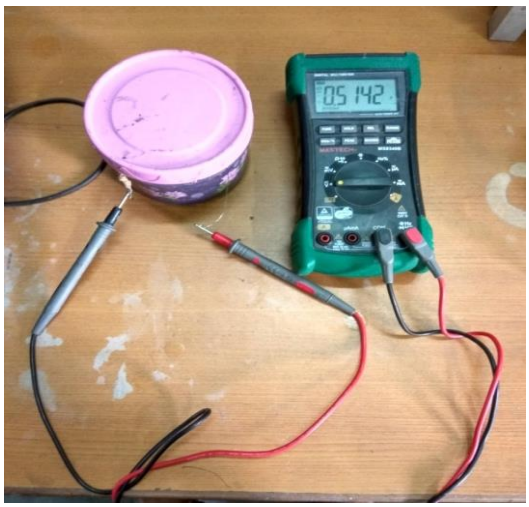

Fig. 1: Completely assembled MFC

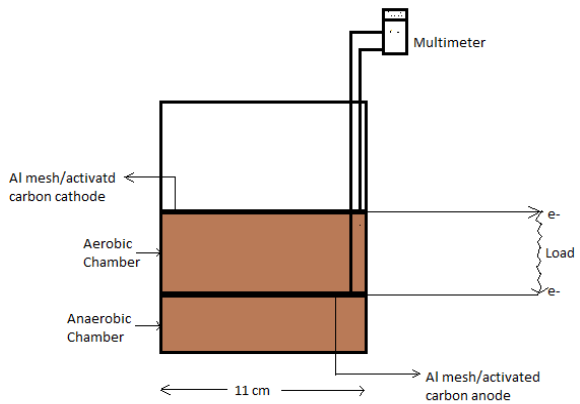

Fig. 2: Schematic of ACMFC

A digital multimeter (Mastech MS8340B) is used for voltage and current measurement). Glucose (1g/10 mL in distilled water) is used as substrate. A sealing material is used to stick activated carbon on the aluminum mesh (fevi quick).

MFC Design and Consideration

A cylindrical shape mediator less microbial fuel cell was designed in Fig. 2. Cylindrical shape MFC is easy to construct and is relatively inexpensive than other design configurations.

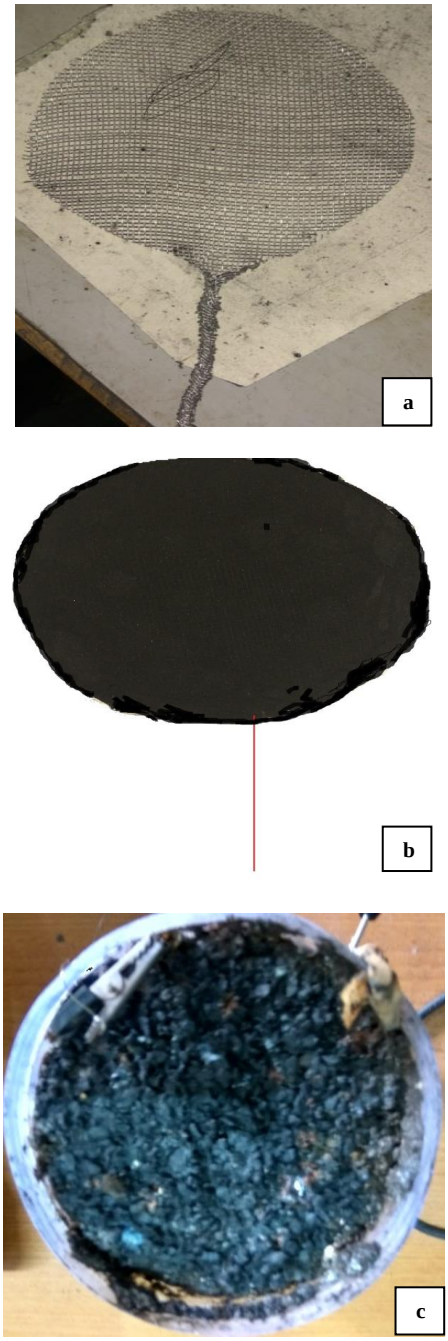

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Fig. 3: (a) Aluminum mesh; (b) Activated carbon on aluminum mesh for cathode and anode; (c) Cathode chamber; (d) anode chamber

Anode and Cathode Chamber

Anode and cathode electrodes were identical and were made of activated carbon stuck on the aluminum mesh to eliminate the galvanic effect as activated carbon is the most suitable material for electron conducting and is cheap also as well as it is biocompatible and helpful in the growth of bacterial biofilm. The diameter of the anode and cathode electrodes was 11 cm and the height up to sludge filled was 2 for the anode and 3.5 cm for the cathode Fig. 3. Hence the volume was 190.06 for the anode and 332.5 cm^3 for the cathode chamber. The total surface area of both electrodes was 189.97 cm^2.

Results

Cell behavior was examined using the MFC system explained in the preceding section by monitoring Open Circuit Voltage (OCV) and open circuit current. These findings are discussed in detail in the upcoming section.

Open Circuit Voltage (OCV)

The OCV was monitored from the very start to the end of the experiment, which lasted a total of 25 days. The voltage was measured with an electronic multimeter. The data (Table 1) was obtained at least three times a day at 2 h gaps and averaged. Figure 4 depicts the OCV vs. Time relationship. It was shown that OCV initially grew as days passed due to an increased growth rate of microorganisms, reaching a maximum value of 650 mV on the 16th day and remaining steady until the 18th day, but then dropping to 439 mV due to a fall in the microbial population. On the 19th day, after being given glucose (substrate), there was a significant jump in OCV as the bacteria began to proliferate again, reaching up to 504 mV, resulting in a constant value and a steady graph.

Table 1: Profile of experimental data for OCV, power, and current with respect to time (in the absence of external resistance)

Time (days)	OCV (mV) absence of external resistance	Power (μW)	Current (μA) absence of external resistance
1	6.7	0.000	0
2	15.0	0.075	5
3	50.0	0.500	10
4	96.0	1.152	12
5	102.0	2.040	20
6	105.0	2.625	25
7	120.0	3.960	33
8	154.0	5.852	38
9	205.0	9.020	44
10	224.0	10.528	47
11	353.0	17.650	50
12	400.0	21.200	53
13	455.0	24.115	53
14	488.0	25.376	52
15	556.0	28.120	52
16	650.0	36.400	56
17	647.0	36.232	56
18	649.0	36.595	55
19	455.0	24.570	54
20	439.0	26.340	60
21	448.0	26.880	60
22	487.0	29.707	61
23	500.0	30.500	61
24	498.0	30.876	62
25	504.0	31.248	62

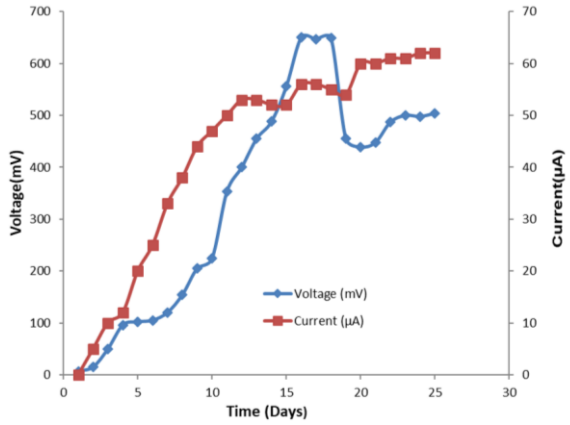

Fig 4: Variation of Open Circuit Voltage (OCV) with current and time

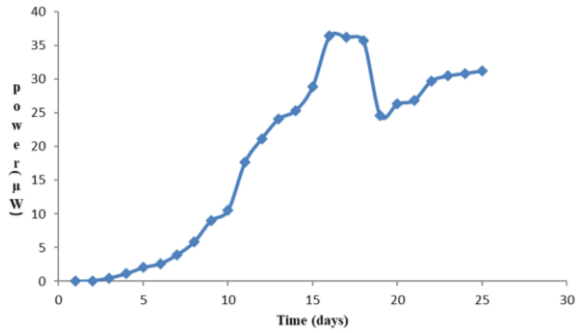

Fig 5: Variation of power with time

A multimeter was used to measure the current, just as it was for the OCV. The average was calculated by obtaining readings three times a day at 2 h intervals. It was discovered that the produced current increased significantly from day 1 until the 12th day, after which it practically delivered a constant value. After introducing substrate, the highest value of 62A was attained and it then gave a constant value. Because no external resistance was utilized, the current recorded was an open circuit current. As a result, the current produced was caused by intrinsic impedance.

Production of Power

Power was calculated by multiplying open circuit voltage and open circuit current. Just like OCV and current power also showed the same trend Fig. 5. There was a definite increase in the generated power from day 1 to the 16th day, (i.e., 36.4 µW) and then it almost gave a constant value up to day 18. There is a decrease in power after day 18th because of the decline in the microbial population, which goes down to 24.57 µW. After adding substrate on the 18th day, the power again started increasing because of the increase in the microbial population.

Discussion

Power generation in MFCs will necessitate maximising proton transport rates while minimising oxygen transport by lowering the system's internal resistance. Many MFC investigations have employed Nafion membranes, and it is known that oxygen penetration across these membranes can lower MFC Coulombic efficiency (Min *et al*., 2005). Because these bacteria will scavenge any dissolved oxygen, preserving anaerobic conditions in the anode chamber, the use of mixed cultures may help minimise the impacts of oxygen penetration into the anode chamber (Kim *et al*., 2007). However, because aerobic bacteria do not contribute to electricity generation, any oxygen diffusion into the system will result in substrate loss and decreased Coulombic efficiency (Oh *et al*., 2004; Oh and Logan, 2006). MFCs might be used to generate electricity from wastewater, including home wastewater and industrial wastewater with a high starch content (Min *et al*., 2005).

Conclusion

The primary intent of this study was to find an alternative for electrodes such as carbon cloth and carbon fibers, a common but expensive electrode used in MFCs. For the creation of an electrode in an ACMFC without a metal catalyst, an affordable activated carbon was employed. The voltage generated by the manufactured MFC was satisfactory. However, there is a lot of room for advancement in MFC technology and power output because the current is too low for usage in autos, electronic gadgets, healthcare equipment, and various commercial uses. Modifications to design elements will result in better results. To generate high power, adequate electrodes, anode chamber volume, and an acceptable resistance are required.

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Author's Contributions

Ahmad Nawaz: Conceptualization, methodology, software, validation, formal analysis, investigation and writren original drafted.

Ram Sharan Singh: Conceptualization, methodology, reviewed, edited, resources and supervision.

Ethics

The authors declare that they have no competing interests.

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