The principle of a Microbial Fuel Cell

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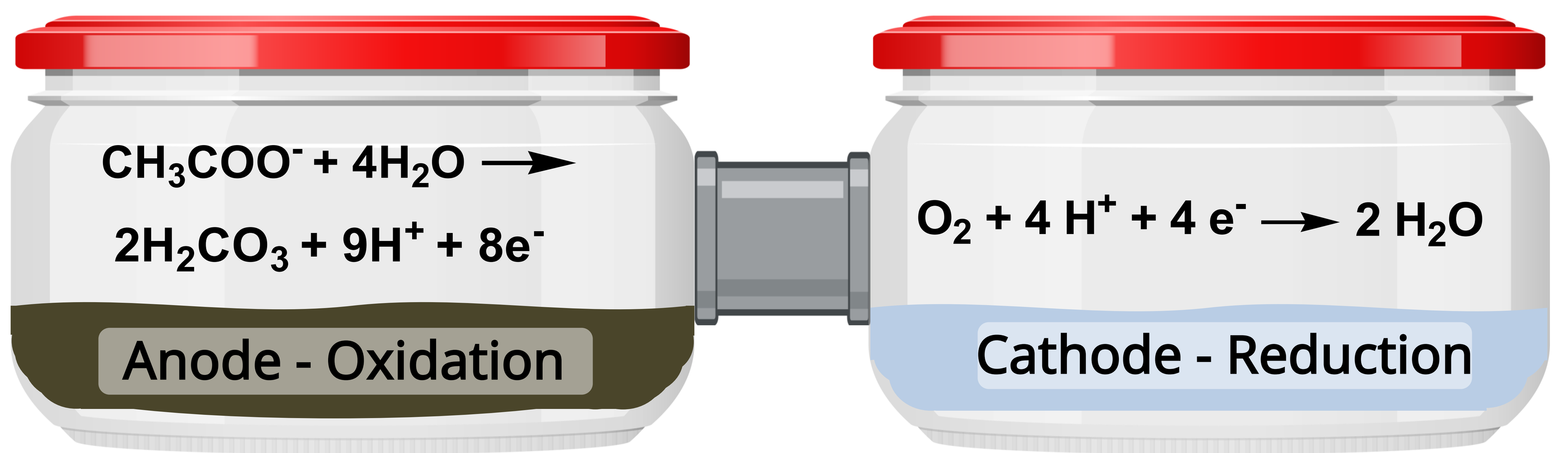
Introduction

The growing need to replace fossil fuels and to manage organic wastewater sustainably has increased interest in technologies that can recover energy from waste streams. Microbial fuel cells (MFC) offer a promising solution as they convert chemical energy directly into electricity using electroactive microorganisms. Unlike conventional fuel cells that require chemical fuels, MFCs operate on organic matter naturally present in sludge, making them inexpensive and environmentally attractive[1].

A MFC consist of two chambers, an anode and a cathode chamber connected by a salt bridge that enables ionic transport. In the anode chamber, anaerobic microorganisms oxidize organic substrate such as acetate, releasing electrons[2]. These electrons flow through an external circuit toward the cathode where oxygen is reduced.



Together these reactions generate a potential difference between electrodes, allowing electrical power to be produced as electrons pass through an external resistance.

The objective of this research is to maximize the electrical power output by examining how electrode material, electrode surface area and substrate addition can be optimized to improve the electrochemical performance of the Microbial fuel cell.

Materials and methods

The microbial fuel cell, shown in Figure 1, was constructed as a two-chamber system, in which the anode and cathode chambers were separated by a salt bridge (3,4 g agar-agar/ 12,6 g KCl mixture in 170 mL tap water) to ensure electrical neutrality. The anode chamber contained anaerobic sludge (from TWZ Diksmuide) with sodium acetate trihydrate as the organic substrate, while the cathode chamber was filled with a 500 mL of 1M KCl solution. Both chambers were continuously stirred at room temperature.

In the experiment, two electrode materials were compared:

- A platinum electrode (11,4 cm^2 and 22,8 cm^2)
- A carbon electrode, contained aluminium meshes coated with active carbon paste (121 cm^2 and 7 times larger).

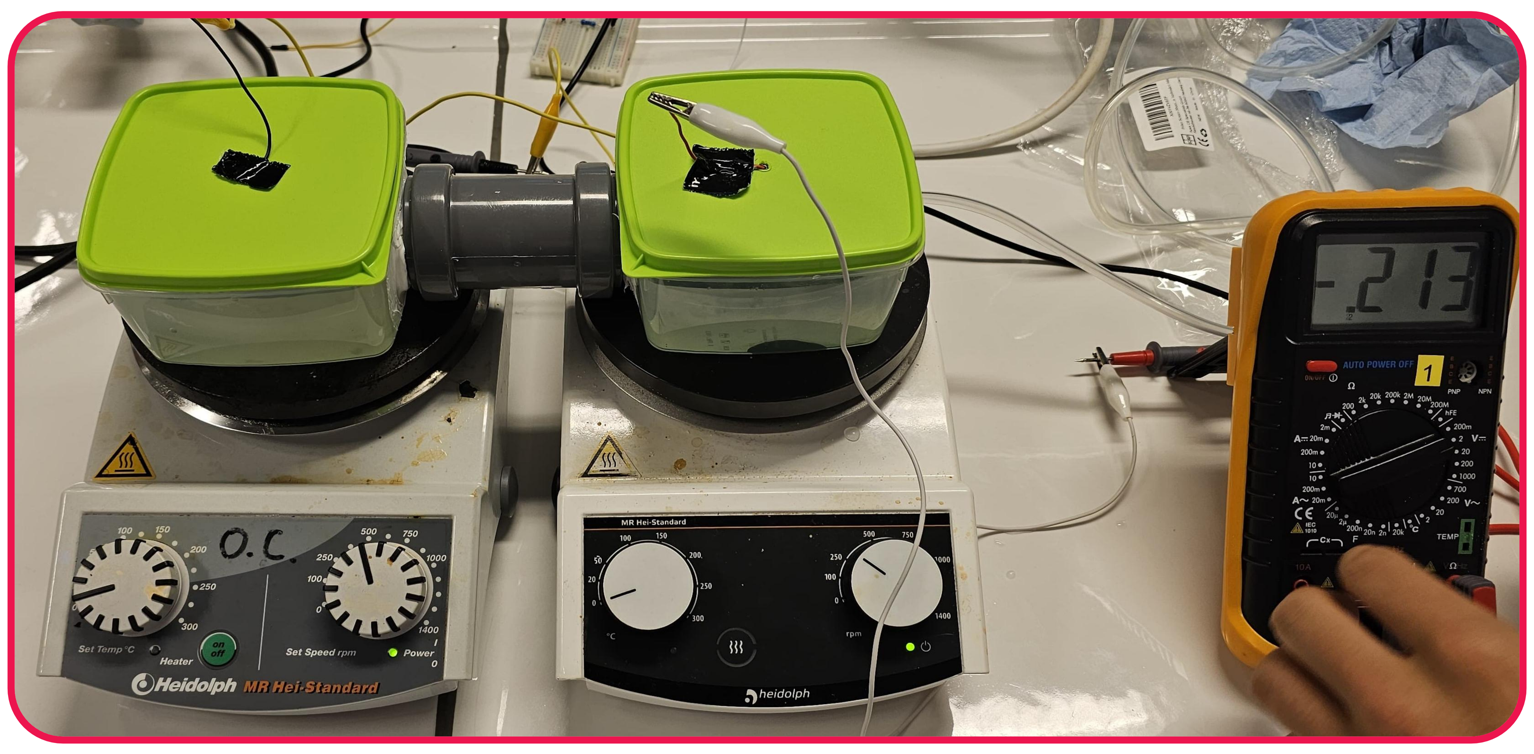


Figure 1: Setup of Microbial Fuel Cell

The performance of the MFC was characterized by measuring the voltage U, across a variable external resistance $R_{ext.}$ From these measurements, the polarization Curve and Power Curve were established. The internal resistance R_{int} was derived from the slope of the linear region of the Polarization Curve[3].

Results and discussion

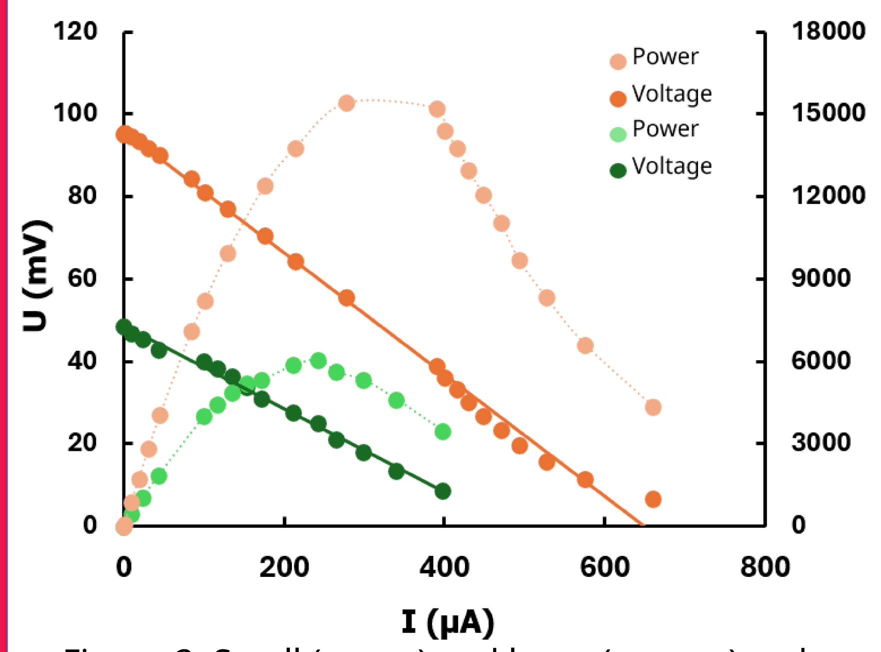


Figure 2: Small (green) and large (orange) carbon electrode surface

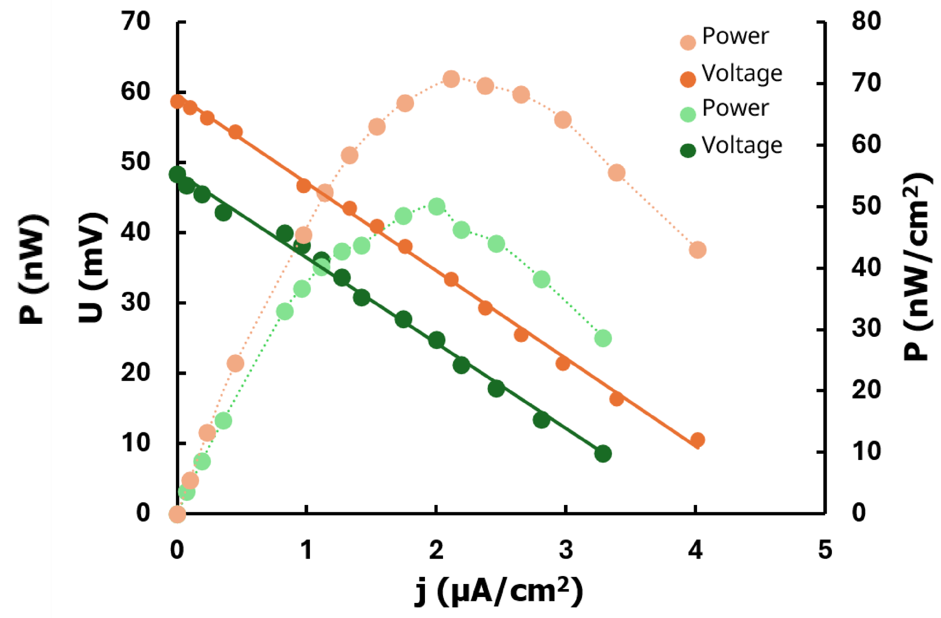


Figure 3: Carbon electrode with (orange) and without acetate (green)

Figure 2 shows that increasing the carbon electrode surface area by a factor of 7 leads to an increase of the maximum power by a factor of 2,5. The highest measured power during this study was 15401 nW. This improvement is attributed to the larger number of electrochemically active sites available for electron transfer.
Compared to platinum, carbon electrodes perform better due to their porous structure which provides a much larger effective surface and thus a lower internal resistance

Figure 3 shows that the addition of acetate increases the cell voltage across the entire polarisation curve and leads to an increase of 41% in maximum power density, demonstrating the positive effect of substrate availability on MFC performance.

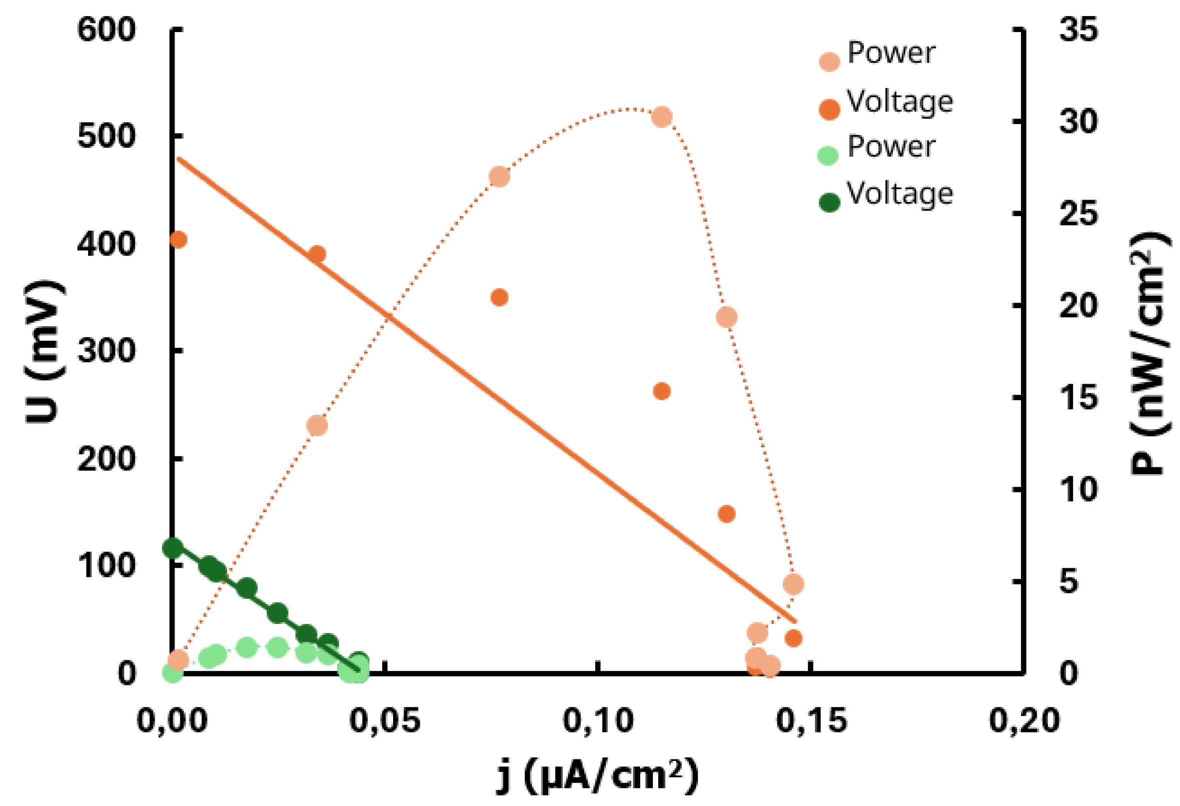


Figure 4: Platinum electrodes without (green) and with sludge (orange)

Figure 4 shows that without sludge, the system shows a low maximum power density of 1,4 nW/cm^2. With sludge the maximum power density increases to 30,2 nW/cm^2. This large increase confirms that the system operates as a microbial fuel cell.

Conclusion

This study shows that the performance of a MFC is influenced by electrode material, electrode surface area and substrate addition. **Carbon-based** electrodes **outperform platinum** electrodes by delivering higher power outputs, while remaining inexpensive. **Increasing** the carbon **electrode area improves** the **maximum power output**. **Substrate addition increases cell voltage** and **power density**, provided that the internal resistance is sufficiently low . Measurements with sludge confirm that the generated current originates from microbial activity, **validating the system as an MFC**.

Overall, the results show that MFCs constructed from low-cost materials are technically feasible, and that power output can be improved through optimized electrode design and operating conditions.

References

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