Development and Performance Evaluation of Microbial Fuel Cells for Simultaneous Treatment of Organic Waste and Bioelectricity Generation.

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DOCTOR OF PHILOSOPHY

By

MANISHA VERMA

School of Biochemical Engineering
Indian Institute of Technology
(Banaras Hindu University)
Varanasi – 221005
India

Roll No. 18011010 **2023**

Chapter 7

(Overall Conclusion and Future Perspective)

7.1 Overall Conclusions

In the present work, different types of organic waste, including banana peels, sweet lemon peels, newspaper, mixed fruit peels, diluted cow urine and spent engine oil, have been treated and valorized for bioelectricity generation using MFCs. With sweet lime peel slurry co-culture of *Saccharomyces cerevisiae* with isolated cellulolytic bacteria *Enterobacter cloacae* strain IIT BHU M2V2 at anode chamber has emerged more effective than *Saccharomyces cerevisiae* alone. At the cathode, diluted cow urine has emerged as a suitable medium for algae growth instead of other costly synthetic algae culture media. The growth of microalgae at the cathode chamber resulted in enhanced power density generation. Besides electricity generation, microalgae growth at the cathode chamber has been found to be effective for COD removal, nitrate-nitrogen removal, ammonium-nitrogen removal, and phosphate phosphorus removal. It has been observed that microalgae have been not so effective in the case of spent engine oil catholyte.

Enterobacter cloacae strain IIT BHU M2V2 has electrogenic and cellulolytic activity. Adequate power generation was noticed by using newspaper powder, dead, dried microalgae powder and mixed fruit peel powder separately with *Enterobacter cloacae* strain IIT BHU M2V2. Banana peels are abundant in phenolic compounds, essential macro and micronutrients. These nutrients support the growth of the indigenous microbial community inside the anode chamber. It has been noticed that banana peel slurry supports microbial growth better than banana peel powder. The combination of banana peel slurry with *Saccharomyces cerevisiae* has been achieved greater power density as compared to the YPD medium with *Saccharomyces cerevisiae*. Metagenomic analysis of banana slurry revealed that *Stenotrophomona, Flavobacterium, Chryseobacterium* and *Pseudomonas* were the most abundant genera. Pseudomonas is well known electrogenic genera for MFC. Decision Tree regression analysis was used to predict different combinations of input variables (Temperature, pH, slurry concentration, external resistance, and pretreatment), generating high power density. Predictor important function revealed that temperature, external resistance, and slurry concentration were highly influential input variables affecting high power density generation.

7.2 Future research needs and engineering implications

Most of the organic waste comes from the food and agriculture industries. Such organic waste is rich in starch, lignin, cellulose, and pectin. Optimization and development of lignocellulolytic microbial consortia could be more effective for high power density generation with simultaneous waste treatment using MFC. For scaling up such MFC systems, several other parameters must be optimized, including electrode surface area, reactor design, substrate concentration, composition, mass transfer, mixing, electrolyte conductivity, pH, microbial community, oxygen concentration, and external resistance. Highly complex machine learning algorithms such as support vector machine and random forest can be used to optimize these additional input parameters. More focus has been needed to develop economic and efficient alternatives for proton exchange membranes and electrodes. The study can be further conducted by stacking up individual units and connecting them in a series or parallel circuit arrangement to obtain higher power outputs. In addition, the findings of the present work will serve to stimulate not only industries but also the world around us. The findings of optimization studies may be used by industries to implement MFCs for waste treatment. There will be no need for any extra laboratory tests, and the results will be able to be immediately applied at both the pilot and large-scale levels.

Scaling up MFCs from laboratory-scale prototypes to commercially viable systems pose several challenges. Additionally, improving the power density of MFCs to enhance their economic feasibility and exploring the integration of ML algorithms to optimize performance are areas of interest.

As MFCs scale up, issues related to mass transfer become more prominent. Efficient transfer of substrates and products across larger distances can be challenging. Design modifications and optimization of reactor configurations are needed. Maintaining a high surface area for electron transfer becomes more challenging at larger scales. Developing scalable electrode materials and configurations is crucial. Achieving and maintaining a robust biofilm on larger electrode surfaces is challenging. Strategies to promote biofilm growth and stability at scale are needed. The cost of materials, construction, and maintenance increases with scale. Finding cost-effective and durable materials becomes crucial for commercial viability. Larger MFC systems may require more complex monitoring and control systems. Ensuring stability and reliability while managing increased complexity is a challenge. Research on advanced electrode materials with high conductivity, surface area, and durability is essential for improving power density.

Identifying or engineering electrogenic microorganisms with high metabolic rates and efficient extracellular electron transfer capabilities can enhance power generation. Fine-tuning environmental factors like pH, temperature, and nutrient concentrations can significantly impact microbial activity and electron transfer rates. Integrating MFCs with other renewable energy technologies or energy storage systems can enhance overall performance and power density. ML algorithms can be employed to optimize operating conditions by analysing real-time data, leading to improved efficiency and power output.

In summary, addressing scaling challenges, improving electrode materials, optimizing operational conditions, and integrating machine learning for enhanced control and optimization are key strategies to make MFCs more commercially viable and efficient. Collaboration between researchers, engineers, and data scientists will be essential for advancing these technologies.