Development of algae assisted Microbial Fuel Cell for power generation and algae cultivation

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Conclusions and Future Prospective

The study aimed to develop low-cost algae assisted microbial fuel cells. The objectives were framed considering the existing bottlenecks in the MFC technology. The primary limitations which inhibit the transition of MFC technology from the lab to the field include the high operational cost associated with MFC reactors. This includes expensive cathode catalysts & proton exchange membrane, the requirement of continuous supply of electron donor at the anode and electron acceptor at the cathode, low power output, and energy recovery in scaled-up reactors. Therefore, a closed-loop process that does not rely on the supply of external electron donors at anode and acceptor at the cathode was developed. Also, the low-cost separators and MFC chambers were used to test the process scale-up.

At first, the study was carried out at 100 ml scale to develop a closed-loop, self-sustainable system that is not dependent upon the external supply of electron donor substrate. Therefore, a lab-scale algae assisted MFC was constructed for power generation and simultaneous algae cultivation. The algae biomass in the cathodic chamber was harvested and subjected to lipid extraction. The residual lipid extracted algal (LEA) biomass was introduced as an electron donor substrate in the anodic chamber. The LEA underwent a simple drying procedure before being used as an anodic substrate. Besides, microbial consortia capable of degrading LEA biomass was developed and studied.

This study demonstrated the successful use of LEA biomass as an anodic substrate for the first time in literature. The power density and electrical energy generated were 2.7 W/m^3 and 0.1 kWh/m^3, respectively. The process was a zero-waste and zero-carbon system, turning out to be a net energy producer. The power output and algae production rates were low in small scale and needed enhancement.

The MFCs were then scaled-up to a level of 10 L. The reactor was fabricated using low-cost materials such as rock phosphate blended clayware as separator cum anode chamber and low-density polythene bag as a cathodic chamber. The reactors were operated outdoor to eliminate the cost associated with artificial illumination. LEA biomass was employed as an electron donor at the anode. The MFCs performed well in all aspects, namely energy recovery, algae productivity, and operation cost. The 5% RP-MFCs exhibited 0.307 $kg/m^3/d$ algal productivity, 0.09 $kg/m^3/d$ lipid productivity. The most abundant genera predicted in the system include *Alicycliphilus*, *Dechloromonas*, *Azospirillum*, *Paracoccus*, and *Geobacter*. All of these genera are known to degrade complex substrates. The system generated a net 11.53 kWh/m^3 energy at the cost of $11.225 only.

For the first time, this study reported the operation of the outdoor algae assisted MFC at a 10 L scale. The enhanced algae biomass in scaled-up MFC showed RP's potentiality as a low-cost separator and algal growth promoter. The energy and cost analysis indicated a promising system that can be further developed into a sustainable process.

Further work involved the development of a low-cost cathode catalyst. The graphite/CuO composite electrode showed promising results compared with graphite/Fe_3O_4, graphite/MnO_2 composite electrode, and conventionally used Pt-coated carbon cloth in all aspects as power density, algal growth, and electrochemical activity. It was observed that Pt-coated Cathode material is not suitable for algae-assisted MFCs. It hinders the growth of algae in the cathodic chamber, which eventually leads to the collapse of the system. Considering the limitation of Pt-based catalysts in algae assisted MFCs, it becomes even more necessary to develop an efficient oxygen reduction catalysts particularly suited to algae-based cathodes.

The results obtained from the study are promising. However, the massive scope for improvement exists. This warrants further studies on MFC design and biological parameters to enhance the energy output from the system. This includes the development of anode-cathode catalysts, suitable algae species that grow effectively in MFC conditions, recycle of anode effluent, process automation, and aeration that can increase the algae growth rates substantially. The electrical energy obtained from the system may also be managed effectively using power management systems to meet the fraction of process aeration requirements. Furthermore, introduction of genetically modified algae in the cathode compartment for enhanced oxygen production, high nutrient recovery and increased yield of biofuels, can be an additional asset for this technology. In addition to this, serious efforts must be made in order to popularize this technology in field application, considering the techno-economic analysis. The technology is worth commercial application as it integrates algae cultivation and can be developed into a bio-refinery for energy and related industries.

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