CONSORTIUM BUILDING FOR PEM MFC USING SYNTHETIC MEDIA AS SUBSTRATE

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Abstract: Microbial production of electricity is an important form of bioenergy since Microbial Fuel cells (MFC) offer the possibility of extracting electric current from a wide range of organic wastes and renewable biomass. Factors affecting the MFC operational effectiveness are the MFC design and the bacterial metabolism and electron transfer. The purpose of this study is to identify species which are responsible for electricity generation so as to build a suitable consortium and to investigate the relative efficiencies between the microbial consortiums. Enrichment by repeated transfer of a bacterial consortium harvested from the anode compartment of a MFC with synthetic media as a substrate increased the output from an initial level of 34 mA to a maximal level of 363 mA. Scanning electron microscope image indicated that the enhanced microbial biofilm deposition over the electrode which were not initially detected in the community.

Keywords: microbial fuel cell; proton exchange membrane; microbial consortium; electricigens

Introduction

MFCs are bioelectrochemical systems which convert biomass into electricity through the metabolic activity of the microorganisms. Electrons produced by the bacteria from the substrate are transferred to the anode under anoxic conditions and flow to the cathode linked by a conductive material containing a resistor. The electron donor can be a reduced product of microbial metabolism that facilitates electron transfer by accepting electrons from the microbes and donating them to the anode. The cathode may be exposed to the air or submerged in aerobic water. Protons released from oxidation of the organic matter migrate to the cathode through a cation-selective membrane that limits diffusion of oxygen into the anode chamber. Electrons, protons and oxygen combine at the cathode surface to form water.

Current generation in microbial fuel cells (MFCs) is dependent on the presence of exoelectrogenic bacteria that oxidize organic matter and transfer electrons to the anode (Logan, 2008). Pure exoelectrogenic cultures have been tested as inoculums for MFCs, but the power densities generated were usually lower than those obtained using a mixed culture in the same MFC (Ishii *et al*., 2008), although some pure cultures produced power densities equal to or higher than those of the mixed culture (Nevin *et al*., 2008).

A microbial consortium is two or more microbial groups living symbiotically as one could find in activated sludge basins, biofilms found on various soil and aquatic ecosystems. Microbial consortia are efficient at degrading complex organic wastes than single strains of organisms.

The term electricigen was coined to make a clear distinction in the mechanisms of power production in microbial fuel cells (Lovley, 2006). Electricigens are microorganisms that conserve energy to support growth by completely oxidizing organic compounds to carbon dioxide with direct electron transfer to the anodes of microbial fuel cells. Electricity production with electricigens has a number of advantages which include high coulombic efficiency.

In this study several sets of microbial consortium has been built which was then inoculated in synthetic media which produced varying current output.

Materials and Methods

The PEM MFC reactor set up consists of two 1000 ml (14 cm length) plastic container, one for anodic and the other one for cathodic chamber. Both the chambers are separated from each other by a cation exchange membrane (Nafion 117, Dupont & Co. USA). The PEM membrane was connected with the two chambers by union and blanches with a length of 7cm. Three carbon electrodes were used in each chamber. The anodic chamber contains synthetic media as well as the inoculated cultures which form the consortium. The cathodic chamber is filled with water. The transfer of electron takes place externally through circuit and internally through potential difference created by oxygen gradient.

Synthetic media (Composition per litre)

8800 mg NaCl, 3000 mg $NaHCO_3$, 275 mg $CaCl_2$, 1500 mg KH_2PO_4, 2200 mg K_2HPO_4, 10 mg $FeSO_4.7H_2O$, 1.0 mg $ZnCl_2$, 500 mg NH_4Cl, 2.0 mg KCl, 0.1 mg H_3BO_3, 180 mg $MgSO_4.7H_2O$, 1mg EDTA, 450 mg $(NH_4)_2SO_4$. To this medium, a carbon source (glucose 2000 mg) was added. The autoclaved media was filled in the anodic chamber of the MFC.

Consortium Building

Five sets of microbial consortium have been built for PEM MFC. The microbes were taken in different combination and used in synthetic media PEM MFC which showed relative efficiency of power output. All microorganisms were procured from MTCC, IMTECH, India.

Set 1

Escherichia coli, *Klebsiella pneumonia, Pseudomonas aeruginosa, Proteus vulgaris, Salmonella typhii* and *Staphylococcus aureus*

Set 2

Pseudomonas aeruginosa, Alcaligenes faecalis, Enterococcus gallinarum, Aeromonas hydrophila, Escherichia coli and *Enterococcus faecalis*

Set 3

Klebsiella pneumonia, Enterococcus faecalis, Enterococcus gallinarum, Staphylococcus aureus, Escherichia coli and Obligatory aerobe *Bacillus subtilis*

Set 4

Proteus vulgaris, Alcaligenes faecalis, Enterococcus gallinarum, Lactobacillus ferment, Lactobacillus plantarum and *Aeromonas hydrophila*

Set 5

Staphylococcus epidermis, Enterobacter aerogenes, Enterococcus faecalis, Alcaligenes faecalis, *Enterococcus gallinarum* and *Aeromonas hydrophila*

These sets of microbial cultures were taken and grown in LB/NB and incubated overnight in a shaker. The well grown cultures were inoculated in synthetic media of anodic chamber of PEM MFCs.

SEM analysis using FEI Quanta 200 FEG

Scanning electron microscopy was done to view the biofilm deposition over carbon electrode surface.

Results and Discussions

All MFCs were kept in room temperature of 37^{o}C for a period of 30 days and the readings were recorded at the interval of 24h.

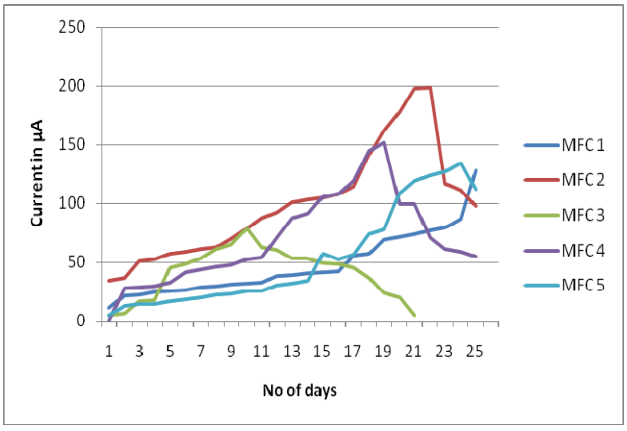


Fig. 1: Relative efficiencies between five sets of consortia

Among all the consortia built, set 2 consortia showed maximum current output.

CFU for set 2 with different microbial load

CFU were calculated for set 2 of 10^{-6} dilution for day 5 with varying microbial concentration of 1, 2 and 3 ml.

Table 1: Number of colonies at 10^{-6} dilution on day 5 for set 2 MFC

MFC set up	No of colonies
Set 2(A)	**3.3×10^7**
Set 2 (B)	**5.6×10^7**
Set 2 (C)	**16.5×10^7**

Day 21 (275 mA) Day 21 (307 mA) Day 21 (363 mA)

Set 2 PEM MFC with 1 ml culture **Set 2 PEM MFC with 2 ml culture** **Set 2 PEM MFC with 3 ml culture**

Fig. 2: Comparative analysis of set 2 PEM MFC with varying microbial load.

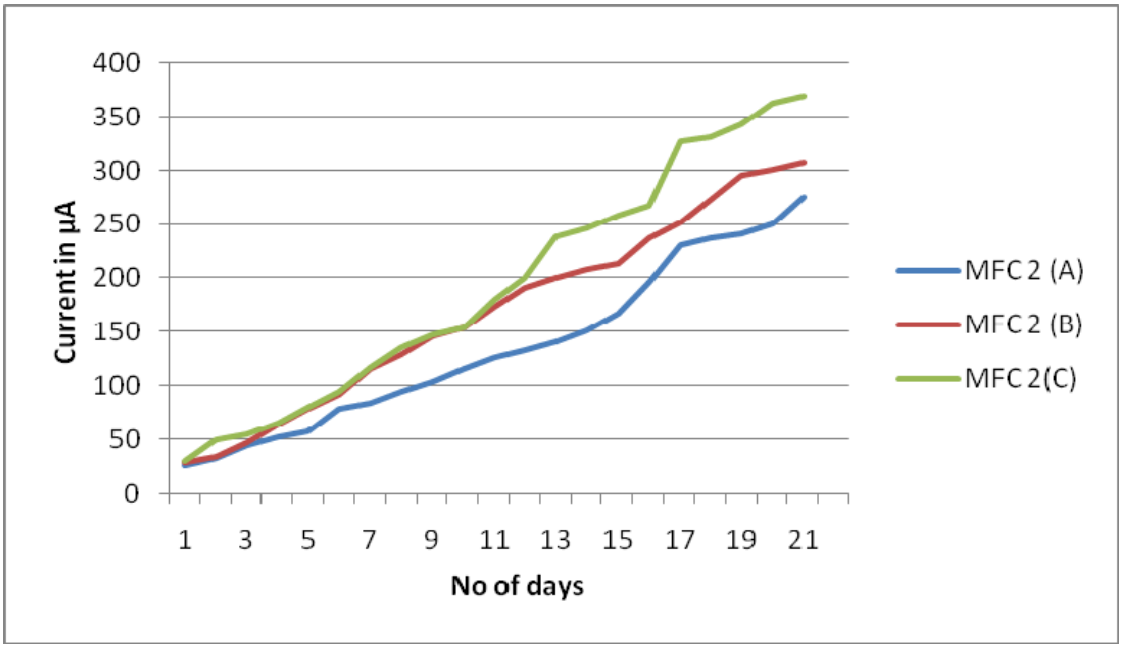
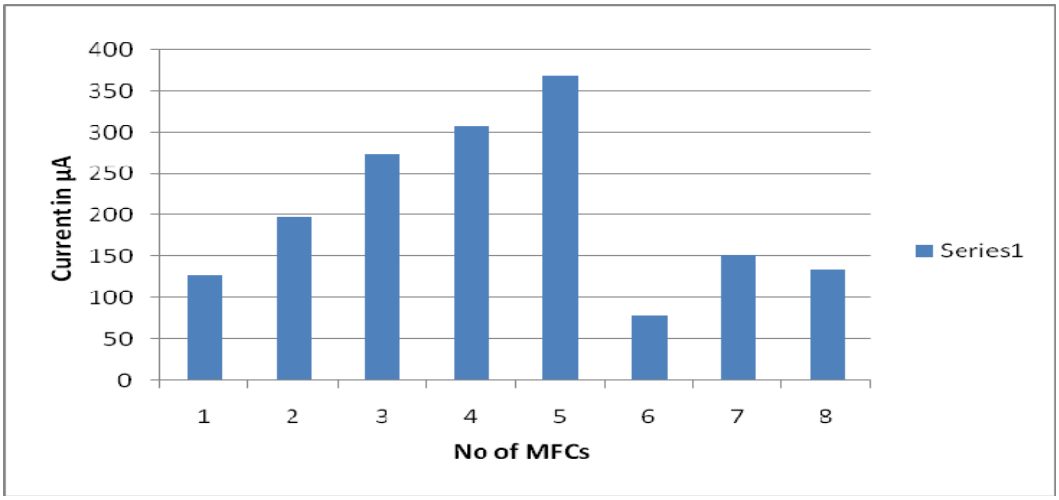


Fig. 3: Relative efficiencies between MFC set 2 with different microbial concentrations.

Table 2: Consolidated readings

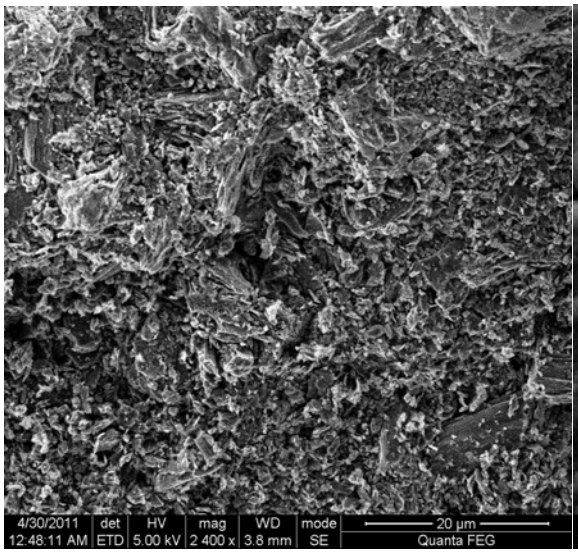
MFC Consortium Set up	Maximum current (µA)
Consortium 1	128
Consortium 2	198
Consortium 2(A)	275
Consortium 2(B)	307
Consortium 2(C)	363
Consortium 3	079
Consortium 4	152
Consortium 5	134

Fig. 4: Bar diagram representing maximum current output for each consortium

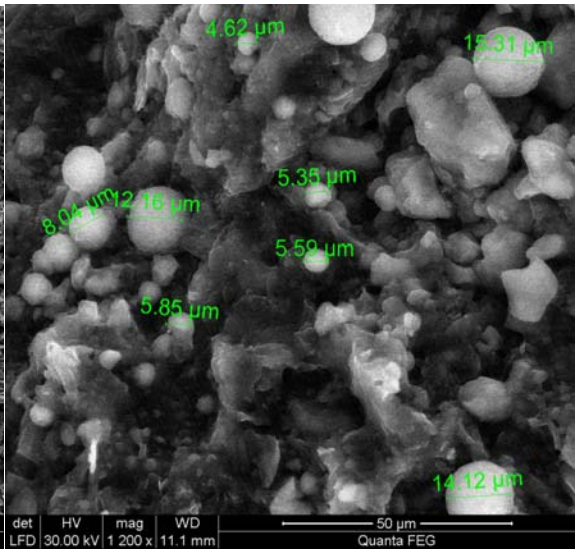


SEM analysis

Fig. 5: SEM image of plain anode



Biofilm deposition over anode



Conclusion

Under present investigation, enrichment by repeated transfer of a bacterial consortium harvested from the anode compartment of a MFC using synthetic media as a substrate increased the output from an initial level of 34 mA to a maximal level of 369 mA. This result was obtained with an average loading rate of 1g of glucose liter/day. MFCs operated using mixed cultures achieve greater power densities than those with pure cultures. Thus, different microbial consortiums give varying current output. There has been an increase in recent years in the number of reports of microorganisms that can generate electrical current in microbial fuel cells. Further studies would be necessary to optimize the electricity production from this synthetic media PEM MFC. Efforts should be made to maximize the transport of electrons from bacteria to the electrode surface by identifying efficient electricigens.

References

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