Biological Fuel Cells: Offer Solutions as Alternative Electricity Generation

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Abstract

Interest in MFC is gaining momentum worldwide. Micro fuel cells are devices for generation of electricity from organic substrates through catalytic reactions of microorganisms. In a microbial fuel cell, the bacteria are stimulated to transfer their electrons to an electrode, from which the electrons then depart to external electrical circuit The recent electricity crisis has reinvigorated the interests in MFC as a way generate electric power. An attempt was made to generate electricity from different micro organisms using wastewater. In this study, a Microbial fuel cell (MFC) employing low-cost material, mixed culture without non toxic mediators was evaluated. Citric acid serves as non toxic mediator. This study opens the window to investigate more about MFC's. The present investigation documented the advantage of both wastewater treatment and electricity production in a single system

Key words: MFC, Waste water, Citric acid, Electricity, Mixed culture

Introduction

Electricity has become indispensable in the modern era and there is an increasing dependency of the mankind on electrical energy. Two key challenges in the quest for sustainable societies are energy generation and waste disposal. Microfuel cells can provide an elegant solution by linking both tasks (Scholz and Schroder, 2003). Generally a microbial fuel cell is an electrochemical device capable of continuously converting chemical energy from organic compounds, such as simple carbohydrates or organic waste matter, into electricity by using bacteria as biocatalysts. There are many advantages i.e.,high efficiency due to the direct conversion of the fuel energy into electricity, room temperature operation, low fuel costs, on-toxic by-products release and great organic compounds diversity depending on the metabolic abilities of the micro organisms.Moreover, their configuration opens up untold possibilities for other applications, such as small scale power plants, batteries and sensors. Besides, steps should be taken on a war footing to start new power projects, to enhance the same. S.V. Mohan *et al* documented the advantage of both waste water treatment and electricity production in a single system. It was cost effective, environmentally sound and sustainable due to utilization of waste water as substrate. Presently, research on MFCs using wastewater as substrate is in the initial stages of laboratory evaluation around the world. The reported work so far is mainly based on using the monoculture at laboratory level (Larminie and Dicks ,2003: Niessen,2004: Park and Zeikus,2003: Rabaey et al., 2003). A few studies were reported on using wastewater as substrate for production of electricity (Logan, 2004: Oh and Logan,2005: Scholz and Schroder, 2003). The basic aim of the present study is to design MFCs employing low cost materials, mixed culture of microorganisms with non-toxic mediators, which will have the possibility to be implemented in the wastewater treatment plants.

Materials and Methods

Locations of the sampling sites

All waste water samples were collected from various sources at Tamil Nadu agricultural University in 2008 (Table 1)

Bacterial culture preparation for bio fuel cells

Waste water samples were collected from different sources. (Table.1) *E.coli, Pseudomonas, Bacillus, Azospirillum* were aerobically cultivated in LB medium at 37°C in separate manner. Mixed consortia act as an inoculam. Inoculam was centrifuged and washed with saline buffer. The resultant pellet was enriched in the collected waster water. Citric acid serves as an electron shuttles

MFC construction and operation

The MFC consists of three compartments with carbon electrodes. (Fig1) Three MFCs were connected in series connection. Each chamber was provided with sample port, wire point inputs (top), inlet and outlet ports. Proton exchange membrane (NAFION 117, Sigma) was used to separate the two chambers. Anodes were made of plain carbon while the cathode, except as noted below, contained catalyst (0.35 mg/cm^2, Pt). The

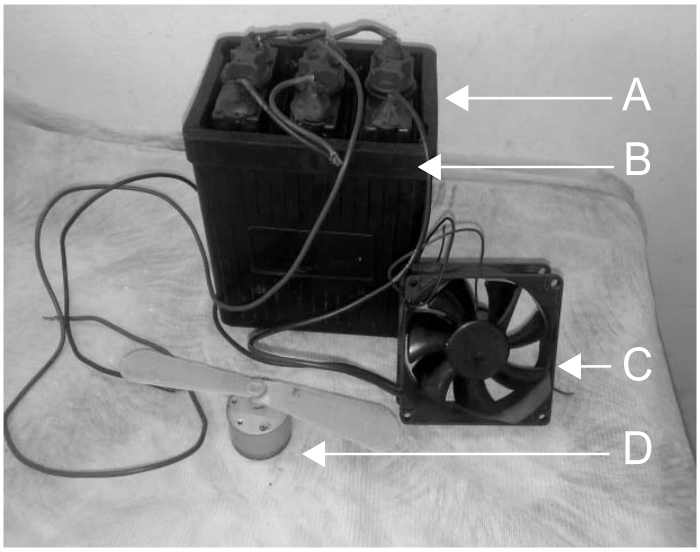


Fig.1: Electricity generation by using mixed culture of bacteria- stacked MFC systems. (A- compartment having an anode and cathode, B- series connection in circuit, C- Electrical load, D-motorised electrical load)

electrodes were attached using copper while with all exposed metal surfaces sealed with non conductive epoxy material (Dexter Corp, N.J., USA).

Analytical methods

Current (*I*) and potential (*V*) measurements were recorded using digital multimeter (Metravi 901). Current densities were calculated for mixed consortia, pure culture, and different waste water. Furthermore, Electron shuttles were designed.

Results and discussion

Waster water samples were collected from different locations (Table1). Results revealed that generation current from glucose enriched waste water by mixed culture. sewage waste water inoculated with mixed culture recorded the highest current density of 1.0 mA followed by the domestic waste water sample. Similar results were reported by several authors (Aelterman 2006: Clauwaert, 2008: Rulkens and .Bien, 2007: Rulkens,2007). Many microorganisms possess the ability to transfer the electrons from the metabolism of organic matters to the anode. Wastewater, soil, marine sediments, fresh water sediment, and activated sludge are all rich sources for these microorganisms (Niessen *et al.*, 2006: Zhang *et al.*, 2006).

MFC was constructed as shown in the Fig1. It is a typical example for stacked MFC systems. This MFC consists of three compartments. Each chamber has an anode, cathode and separated by a PEM (Proton Exchange Membrane). The current densities produced by different microbes and mixed consortia were given in Table 2 and fig2. Mixed consortia have shown highest current density to pure culture. MFCs that make use of mixed bacterial cultures have some important advantages over MFCs driven by pure cultures. It is due to higher resistance against process disturbances, higher substrate consumption rates, smaller substrate specificity and higher power output (Rabaey et al., 2005a; 2005b: Rabaey and Verstraete, 2005).

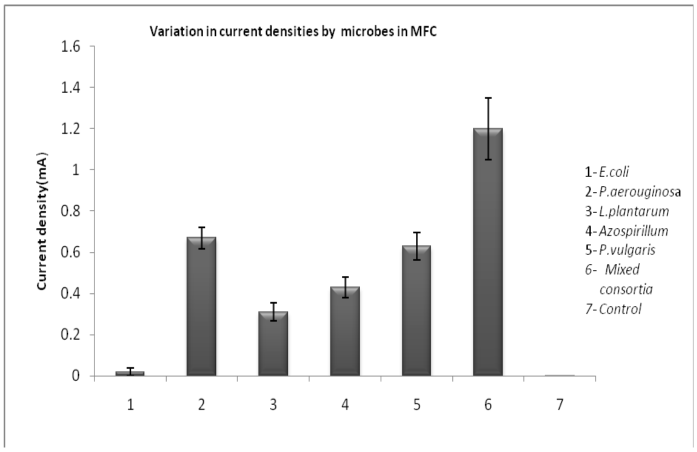
Experiment results showed that bacteria don’t have the capacity to transfer the electrons directly. Hence mediator plays important role in electron transport for those microbes that are unable to transfer the electrons to the anode. Citric acid has not been used as an electron shuttle

Table 1: Source, Inoculam, Current density , Substrate, Location

S.No	Source	Inoculam	Current density	Substrate	Location
1.	Domestic waste water	Mixed culture	0.6mA	Glucose	Hostel, TNAU
2.	Sewage water	Mixed culture	0.9 mA	Glucose	AC& RI, TNAU
3.	Bread industry waste water	Mixed culture	0.5mA	Glucose	Department of Food processing and technology, TNAU

Table 2: Current densities produced by different microbes and mixed consortia

S.No	Microbes used in MFC system	Mediators	Current density (micro A)
1.	*Escherichia coli*	a)Methylene blue b)Citric acid	
2.	*Pseudomonas aeuroginosa*		
3.	*Lactobacillus sp.,*	Citric acid	
4.	*Azospirilum sp.,*	Citric acid	
5.	*Proteus vulgaris*		
6.	Mixed consortia Without mediatorb) Citric acid	Methylene blueCitric acida) —10700320450—6400.023 1100	



in MFC but citric acid was confirmed to be more useful as an electron shuttle for MFC. Citric acid shuttles between the anode and the bacteria transferring the electrons. They take up the electrons from microbes and discharge them at the surface of the anode. It is because of citric acid role in electron transport chain of the microorganisms.There are some examples of bacteria including *Actinobacillus succinogenes, Aeromonas hydrphila, Clostridium butyricum, Klebsiella pneumoniae, Proteus mirabilis, Lactobacillus plantarum* that are able to transfer electrons by the help of mediators(Du et al, 2007: Scholz and Schroder). However, most evidence suggests that electrogenic bacteria are able to oxidize organic compounds to carbon dioxide with extraordinarily high efficiencies(Lovely,2006: Zielkie, 2006). Electricigens such as *Geobactor metallireducens, Geobacter sulfurreducens, Rhodoferax ferrireducens, Shewanella putrifaciens* have been shown to generate elctricty in a mediatorless MFC (Debabov,2007: Lovely and Nevin, 2006:Zhang et al., 2006). Among the five microbes used, *Pseudomonas aeroginosa* has shown the highest current density of 0.7 mA. Similar report was given by Soni (2004).

Conclusion

This is an exciting time in microbial fuel cell research. Microbial fuel cells have been used for several years as biosensors for measuring environmental parameters such as biochemical oxygen demand and water toxicity.MFCs undoubtedly have potential in terms of energy recovery during wastewater treatment. Apart form the electricity production and wastewater treatment, MFC have wider applications in implantable medical devices, bioremediation, environmental biosensors, robotics, bio power in space, portable devices etc., Someday it would replace rechargeable batteries(Logan and Regan, 2006). Instead of plugging into a fixed power outlet and waiting for a recharge, these new batteries would last upto a full month after they charged instantly with a few millilitres of glucose solution to power cell phones, laptops. Hence, MFC perhaps a treasure for future millennium which is visible from the recent analysis by an MNC which found that the world micro fuel cell market for industrial portable devices expects to produce 75 million units by 2013, demonstrating a high market growth rate due to a ramp-up in commercialization.

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