Optimization of Growth Medium in Microbial Fuel Cell for Electricity Production by Paenibacillus

Shikhi Shrivastava[1]
[1]Takshshila Institute of Engineering & Technology
Jabalpur (MP)
shikhi.shrivastava@gmail.com

Rani Ayachi[2]
[2]Takshshila Institute of Engineering & Technology
Jabalpur (MP)
raniayachi@takshshila.org

Abstract: ***Microbial fuel cell (MFC) represents a new method for electricity generation and waste water treatment. Microbial fuel cells are devices that can use bacterial metabolism to produce an electrical current from a wide range organic substrates. This research explores the application of MFC in generating electricity using waste water from Popular bread factory Jabalpur. In order to obtain the aim of this research, a system of MFC with microbe*** **Paenibacillus** ***has been used. As parameter, it was evaluated the electricity produced during MFC operation on variation at different concentration of organic substances.***

Keywords: Electricity, Electrodes, MFC, Paenibacillus, Waste water

1. Introduction

Recent rise in energy costs, rapidly dwindling crude oil supplies and concern over the negative effects of carbon emissions have reignited both public and private interest in finding cheap alternative renewable energy sources. Many "green" energy generating process rely on the metabolic activity of microbes to turn human waste products into useable energy. MFC is considered to be a promising sustainable technology to meet increasing energy needs, especially using wastewaters as substrates, which can generate electricity and accomplish wastewater treatment simultaneously, thus may offset the operational costs of wastewater treatment plant [1].

MFC can be best defined as a fuel cell where microbes act as catalyst in degrading the organic content to produce electricity. It is a device that straight away converts microbial metabolic or enzyme catalytic energy into electricity by using usual electrochemical technology [2]. Various types of the microbial fuel cell exists, differing majorly on the source of substrates, microbes used and mechanism of electron transfer to the anode. Based on mechanism of electron transfer to the anode, there are two types of microbial fuel cell which are the mediator microbial fuel cell and the mediator-less microbial fuel cell.

Mediator-microbial fuel cells are microbial fuel cells which use a mediator to transfer electrons produced from the microbial metabolism of small chain carbohydrates to the anode [3]. This is necessary because most bacteria cannot transfer electrons directly to the anode [4]. Mediators like thionine, methyl blue, methyl viologen and humic acid tap into the electron transport chain and abstract electrons (becoming reduced in the process) and carry these electrons through the lipid membrane and the outer cell membrane [5][6].

Mediator-less microbial fuel cells, on the other hand, use special microbes which possess the ability to donate electrons to the anode provided oxygen (a stronger electrophilic agent) is absent [4][7]. There are variants of the mediatorless microbial fuel cell which differ with respect to the sources of nutrient and type of inoculum used.

In direct electron transfer, there are several microorganisms Eg. Shewanella putrefaciens, Geobacter sulferreducens, G. metallireducens and Rhodoferax ferrireducens, that transfer electrons from inside the cell to extracellular acceptors via c-type cytochromes, biofilms and highly conductive pili (nanowires) [8]. These microorganisms have high Coulombic efficiency and can form biofilms on the anode surface that act as electron acceptors and transfer electrons directly to the anode resulting in the production of more energy [9][10].

Electron transfer by own /artificial mediators: In indirect electron transfer, electrons from microbial carriers are transported onto the electrode surface either by a microorganism's (Shewanella oneidensis, Geothrix fermentans) own mediator which in turn facilitate extracellular electron transfer or by added mediators. The MFCs that use mediators as electron shuttles are called mediator MFCs. Mediators provide a platform for the microorganisms to generate electrochemically active reduced products. The reduced form of the mediator is cell permeable, accept electrons from the electron carrier and transfer them onto the electrode surface [11]. Usually neutral red, thionine, methylene blue, anthraquinone-2, 6-disulfonate, phenazines and iron chelates are added to the reactor as redox mediators [12].

2. Material and method

MFC construction

Electrode: Carbon electrode (Graphite) were used at both the ends of cathode and anode and tightly fixed with containers containing medium, culture and buffer.

Cathodic chamber: The cathode chamber of the MFC was made up of 1.2 liters plastic bottle filled with aerated phosphate buffer (50 mM K2HPO4; pH 7.5) as catholyte.

Anodic Chamber: the 1.2 liters sterilized plastic bottle is used for this purpose. The bottle is surface sterilized by washing with 70% ethyl alcohol and 1% HgCl2 solution followed by UV exposure for 15 minutes. Then the autoclaved minimal medium broth was filled in it. Methylene blue and syringe filter sterilized dextrose solution was added to it and the caps containing electrodes were tightly fixed to it. Then 20 ml of previously enriched culture of bacteria was added.

Salt bridge: The salt bridge was prepared by dissolving 3% agar in 1M NaCl. The mixture was boiled for 2 minutes and casted in the PVC pipe (12cm X 2cm). The salt bridge was properly sealed and kept in refrigerator for proper settling.

Sugar Stock (Carbon Source): Waste water from popular bread factory Jabalpur has been used. It contains organic matter like starch, glucose, and sucrose which is used by bacteria for growth.

Bacteria: Paenibaccilus was used as micro organism (biocatalyst). It is starch digestive bacteria and it is able to convert starch into glucose. This bacterium is not harmful for living organisms as well as environment.

Mediator: Methylene blue is a redox indicators act as electron shuttles that are reduced by microorganisms and oxidized by the MFC electrodes thereby transporting the electrons produced via biological metabolism to the electrodes in a fuel cell.

Circuit Assembly: Two chambers were internally connected by salt bridge and externally the circuit was connected with copper wires which were joined to the two electrodes at its two ends and to the multi meter by another two ends. The potential difference generated by the Fuel Cell was measured by using multi meter.

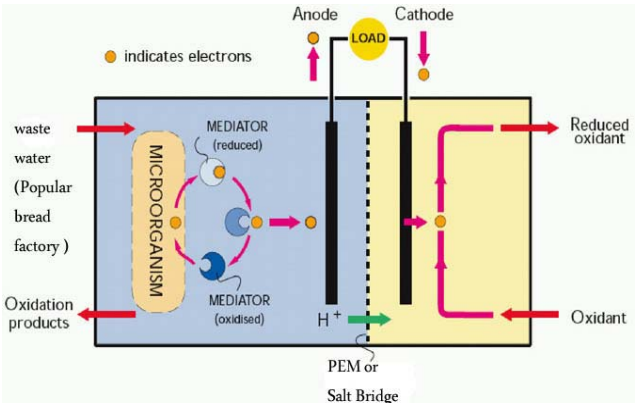

Figure 1: Schematic diagram of MFC

MFC Operation: *This research intends to utilize the waste water generated from popular bread factory Jabalpur to generate electricity in Microbial Fuel Cell (MFC) system. The Paenibaccilus was used as micro organism (biocatalyst). The bacteria will convert sugar components in the waste water into Carbon dioxide, where in the intermediate process will be released electron generating electricity in MFC system.*

All the components of MFC are connected i.e. via salt bridge internally and with externally with wires to the multi meter. The substrate (waste water) was added in the anodic chamber. The anodic chamber was completely sealed to maintain anaerobic condition. The voltage generation was recorded at the interval of 1 hour up to 12 hours for bacterial isolate in presence of mediator. The MFC set up was kept at static conditions. The carbohydrate concentration was tested along with Bacterial isolate for their ability to generate potential difference.

3. Results

Effect of increasing carbohydrate concentration: The carbohydrate source used was glucose. Different concentrations of carbohydrate solutions were made and filter sterilized by syringe filter method. The amount of glucose is already present in popular bread factory waste water is 3g/l and voltage generated by this concentration is 510mV. The concentrations used were 3g/l, 4g /l, 5g/l, 6g/l , 7g/l, and 8g /l (Table-1). It was found that maximum voltage (910mV) was generated when glucose was added in concentration of 5g/ l.

Table 1: Voltage generated by Paenibacillus at different carbohydrate concentrations.

Concentration of glucose solution used in g /l	Maximum voltage generated in mV
3	510
4	720
5	910
6	895
7	870
8	830

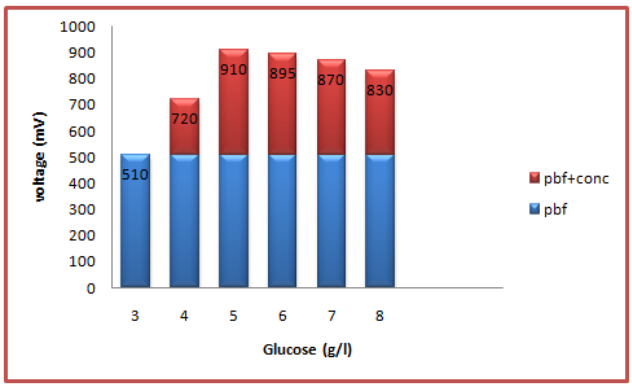

Figure 2: Graph showing voltage generated by Paenibacillus at different glucose concentrations

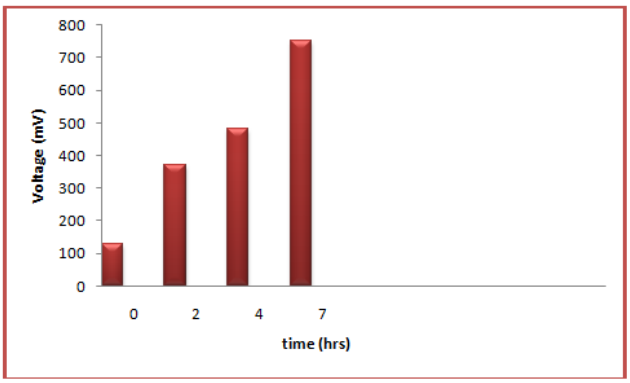

Figure 3: Graph showing voltage generated by Paenibacillus at different time interval

Note:
Pbf: Glucose present in water sample of popular bread factory.
pbf + conc: Glucose present in water sample of popular bread factory and of extra glucose added for maximum voltage generation by bacteria.

Voltage generated by Paenibacillus at different time interval: The MFC was run up to 12 hrs and the voltage was recorded at every 1 hr interval in presence of mediator. There was a definite increase in the voltage with the increase in time as we can see from Table - 2. It was found that maximum voltage was generated 750mV after 7 hours.

Table 2: Voltage generated by Paenibacillus when methylene blue mediator was used

Time (in hrs)	Voltage generated(mV)
At zero hour	130
At 2 hours	370
At 4 hours	480
At 7 hours	750

4. Discussion

Microbial fuel cell is based upon the basic principle in which biochemical energy is converted into electrical energy. Consumption of organic substrate (e.g. glucose) by microorganism in aerobic condition produces CO2 and H2O

$C6H12O6 + 6H2O + 6O2 \rightarrow 6CO2 + 12H2O$

If the terminal electron acceptor oxygen is replaced by mediator then the electrons will be trapped by mediator, which will get reduced and transport to electrons to the electrode at anodic chamber .However when oxygen is not present (anaerobic condition) they produce carbon dioxide, protons and electrons as described below [13].

$C6H12O6 + 6H2O \rightarrow 6CO2 + 24H+ + 24e-$

Based on the result, it was found that maximum voltage (910 mV) was generated when glucose was added in concentration of 5g/ l. The MFC was run up to 12 hrs and the voltage was recorded at every 1 hr interval in presence of mediator. It was found that maximum voltage was generated 750mV after 7 hours.

5. Conclusion

Microorganisms that can combine the oxidation of organic biomass to electron transfer to electrodes put forward the self-sufficient systems that can successfully convert waste organic matter and reusable biomass into electricity. Oxidation of these newly rigid sources of organic carbon does not supply net carbon dioxide to the environment and unlike hydrogen fuel cells; there is no requirement for wide pre-handing out of the fuel or for costly catalysts. With the suitable optimization, microbial fuel cells might be able to power an extensive collection of broadly used procedure. Technology of Microbial Fuel Cell is one alternative of energy production using renewable resource.

References

[1] Rakesh Reddy N, Nirmal Raman K, Ajay Babu OK and Muralidharan A (2007). Potential stage in wastewater treatment for generation of bioelectricity

using MFC, Current Research Topics in Applied Microbiology and Microbial Biotechnology 1 322-326.

[2] Allen R.M., Bennetto H.P. (1993). Microbial fuel cells: electricity production from carbohydrates. Appl Biochem Biotechnol, 39-40:27-40.

[3] Logan, B.E, Hamelers, P., Rozendal, R., Schroder, U., Keller, I., Freuguia, S., Alterman, P., Verstraete, W. and Rabaey, K. (2006). Microbial Fuel Cells: Methodology and Technology. Environmental Science and Technology, Vol. 40: 5181 – 5192.

[4] Scholz, F., Mario, J., Chaudhuri, S.K. (2003). Bacterial Batteries. Nature Biotechnology. Vol. 21(10) pp 1151-1152.

[5] DiBucci, J. and Boland, T. (2011). Turning waste into wealth, the future of microbial fuel cells. Paper #1065, Conference Session #C5, Eleventh Annual Conference, Swanson School of Engineering, University of Pittsburgh.

[6] Kim, J., Han, S., Oh, S. and Park, K. (2011). A Non-Pt Catalyst for Improved Oxygen Reduction Reaction in Microbial Fuel Cells. Journal of the Korean Electrochemical Society. Vol. 14 (2): 71 – 76.

[7] Mohan, V., Roghavalu, S., Srikanth, G. and Sarma, P. (2007). Bioelectricity production by mediatorless microbial fuel cells under acidophilic conditions using wastewater as substrate loading rate. Current Science. Vol. 92 (12) pp 1720 – 1726.

[8] Derek,R L. (2008). The microbe electric: conversion of organic matter into electricity. Current opinion in Biotechnology 19,564-571.

[9] Chaudhuri, S.K., and Lovley, D.R. (2003). Electricity generation by direct oxidation of glucose in mediatorless microbial fuel cells, Nature biotechnology 21, 1229-1232.

[10] Kim, H.J., Park, H.S., Hyun, M.S., Chang, I.S., Kim, M., and Kim, B.H. (2002). A mediator-less microbial fuel cell using a metal reducing bacterium, Shewanella putrefaciens. Enzyme and Microbial Technology 30, 145-152.

[11] Lovley, D.R. (2006). Bug juice: harvesting electricity with microorganisms. Nat Rev Micro 4, 497-508.

[12] Du, Z., Li, H., and Gu, T. (2007). A state of the art review on microbial fuel cells: A Promising technology for wastewater treatment and bioenergy. Biotechnology Advances 25, 464-482.

[13] Scott, K. and Murano, C. (2007). Microbial fuel cells utilizing carbohydrates. Journal of Chemical Technology and Biotechnology. Vol. 82 pp 92 – 100.