Evaluation of the Effect of Cultural Conditions for Efficient Power Generation by Pseudomonas using Microbial Fuel Cell System

Amit Prem Khare[1], Rani Ayachi[2]

[1]Takshshila Institute of Engineering & Technology
Jabalpur (MP)
amitkharepassion@gmail.com

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

Abstract: ***The application of Microbial Fuel Cell (MFC) for electricity generation and waste water treatment has been developing recently. In recent years, researchers have shown that MFCs can be used to produce electricity from water containing glucose, acetate or lactate. This research explores the application of MFC in generating electricity using waste water from Parle Biscuit factory Jabalpur. In order to obtain the aim of this research, a system of MFC with microbe Pseudomonas has been used. As parameter, it was evaluated the power density produced during MFC operation on variation of microbe concentration.***

Keywords: Electricity, Electrodes, MFC, Pseudomonas, waste water

1. Introduction

Energy calamity in India is rising each year, as there is constant acclivity in the price of fuels and also due to depletion of fossil fuels to a larger level [1]. The demand for an alternating fuel has erupted extensive research in discovering a potential, economical and reusable source for energy manufacture. For constructing a sustainable world we require to minimize the expenditure of fossil fuels as well as the pollution generated. These two aims can be accomplished all together by treating the waste water (From disposing waste to using it). Industrial waste, agricultural waste and household waste are ideal substrates for energy productions as they are rich in organic contents.

MFC (Microbial fuel cell) 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].

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) [3]. 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 [4][5].

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 [6]. Usually neutral red, thionine, methylene blue, anthraquinone-2, 6-disulfonate, phenazines and iron chelates are added to the reactor as redox mediators [7]. 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-less microbial fuel cells are use special microbes which possess the ability to donate electrons to the anode provided oxygen (a stronger electrophilic agent) is absent [8][9]. There are variants of the mediator-less microbial fuel cell which differ with respect to the sources of nutrient and type of inoculum used.

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 [10]. This is necessary because most bacteria cannot transfer electrons directly to the anode [8]. 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 [11][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 the containers containing medium, culture and buffer.

Cathodic chamber: The cathode chamber of the MFC was made up of 1 liter plastic bottle filled with aerated phosphate buffer (50 mM K_2HPO_4; pH 7.5) as catholyte.

Anodic Chamber: The 1 liter sterilized plastic bottle is used for this purpose. The bottle is surface sterilized by washing with 70% ethyl alcohol and 1% $HgCl_2$ 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 Parle biscuit factory Jabalpur has been used. It contains organic matter like starch, glucose, and sucrose which is used by bacteria for growth.

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

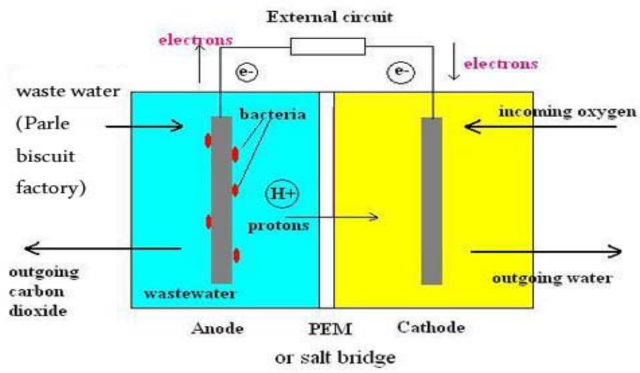

Figure 1: Schematic diagram of MFC

Operation: This research intends to utilize the waste water generated from Parle Biscuit factory Jabalpur to generate electricity in Microbial Fuel Cell (MFC) system. The Pseudomonas 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 parle biscuit factory waste water is 3g/l and voltage generated by this concentration is 505mV. 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 (905mV) was generated when glucose was added in concentration of 5g/ l.

Table 1: Voltage generated by Pseudomonas at different carbohydrate concentrations

Concentration of glucose solution used in g /l	Maximum voltage generated in mV
3	505
4	710
5	905
6	890
7	860
8	820

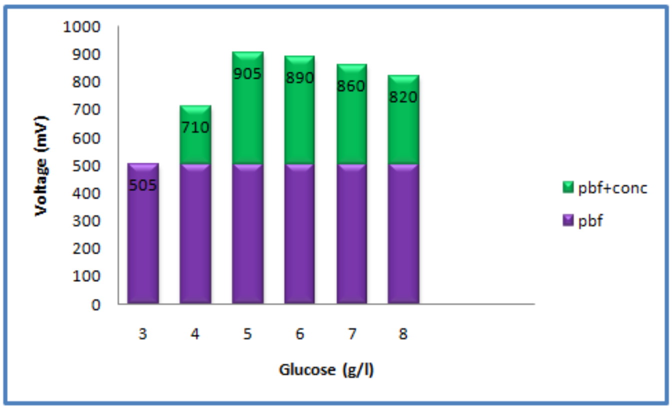

Figure 2: Graph showing voltage generated by Pseudomonas at different glucose concentrations

Note:

Pbf: Glucose present in water sample of parle biscuit factory.

pbf + conc: Glucose present in water sample of parle biscuit factory and concentration of extra glucose added for maximum voltage generation by bacteria.

Voltage generated by Pseudomonas 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 720mV after 7 hours.

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

Time (in hrs)	Voltage generated(mV)
At zero hour	120
At 2 hours	250
At 4 hours	430
At 7 hours	720

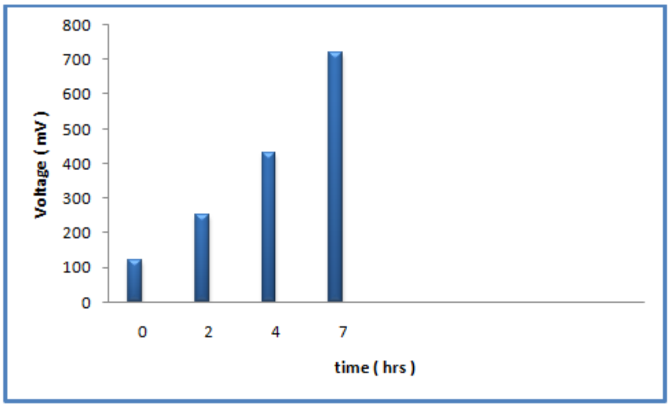

Figure 3: Graph showing voltage generated by Pseudomonas at different time interval

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.

$C_6H_{12}O_6 + 6H_2O + 6O_2 \rightarrow 6CO_2 + 12H_2O$

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].

$C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24H^+ + 24e^-$

Based on the result, it was found that maximum voltage (905 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 720mV 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] Derek,R L. (2008). The microbe electric: conversion of organic matter into electricity, Current opinion in Biotechnology 19,564-571.

[4] 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.

[5] 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

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

[7] 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

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

[9] 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

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

[11] 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

[12] 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

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