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Bio-Electricity Generation Using Kitchen Waste And Molasses Powered MFC

Yash Manjerkar[1], Shivani Kakkar[2], Annika Durve-Gupta*[3]

[1]Department of Biotechnology, Birla College of Arts, Science and Commerce, Kalyan, Thane, Maharashtra, India

[2]Department of Biotechnology, Birla College of Arts, Science and Commerce, Kalyan, Thane, Maharashtra, India

*[3]Department of Biotechnology, Birla College of Arts, Science and Commerce, Kalyan, Thane, Maharashtra, India

ABSTRACT

With the energy demands all over the world, resulting in energy crises and environmental pollution, the need for alternative sources of energy has arisen. The dependence on fossil fuel is unsustainable because of its exhausting supplies and impact on environment. As a result focus is on alternative, renewable and carbon neutral energy sources which are necessary for environmental and economic sustainability. Microbial Fuel Cells (MFCs) are bioreactors that convert chemical energy present in the organic or inorganic compound substrates to electrical energy through catalytic reactions of microorganisms. Electricity generation from MFC using sugarcane molasses and kitchen waste as fuel was investigated in this study. A dual chambered MFC was made using readily available and cheap material. The electrodes used in the MFC were made up of aluminium mesh having a thickness of 2mm. The bacteria present intrinsically in the molasses and kitchen waste were used for the MFC operation. Samples were subjected to BOD and organic matter content analysis to determine the efficiency of the MFC with respect to waste treatment. It was observed that as the time increased, the BOD and organic matter content decreased. The nature of the microbial population seen in the waste also changed. The maximum potential established was 365 mV in the case of molasses and 260 mV in the case of kitchen waste. The MFCs using the kitchen garbage has proved to be a good way to green electricity generation as well as the recycle of organic waste to maintain a healthy and pollution free environment.

Keywords: Microbial fuel cells, kitchen waste, molasses, organic matter, BOD

I. INTRODUCTION

Every year the global energy demand increases. Approximately 86% of the world energy production comes from fossil fuels. Fossil fuels especially petroleum. Coals are being exhausted, leading to an energy crisis in the near future [1-4]. Furthermore the combustion of the fossil fuels adds CO2 to the atmosphere and causes global warming. Consequently there is a need to develop a new type of energy source as alternative to fossil fuels [5-7]. To overcome this energy requirement mankind has been exploring the possibility of alternative sources of energy and has been trying tapping the energy resources of all origin; solar power, nuclear power, water power, wind power, geothermal power, tidal power, wave and ocean currents etc. One of the emerging technologies of interest in this regard is microbial fuel cells (MFCs).

Bioelectricity production is production of electricity by organisms. This is due to release of electrons during their metabolism. These electrons produced can be captured so as to maintain a stable or continuous source of energy production. Bacterial cells when provided a suitable substrate can metabolize the components producing electrons which can be harvested and utilized by connecting them through a circuit. These components can be packed into an assembly called a 'microbial fuel cell' (MFC) proving to be a source of energy [8].

A MFC consists of several components primarily divided into two chambers- anodic and cathodic chamber containing the anode and cathode, respectively. These chambers are separated by a proton exchange membrane (PEM) (Figure 1). The microbes present in the anodic chamber are provided with a favourable substrate which is anaerobically degraded to release electrons which are transported from the anode to the cathode via external circuit and the protons generated are selectively passed through the exchange membrane. Both these products produced due to the action of the microbes in the anodic compartment travel to the cathode and react with oxygen to produce water [9]

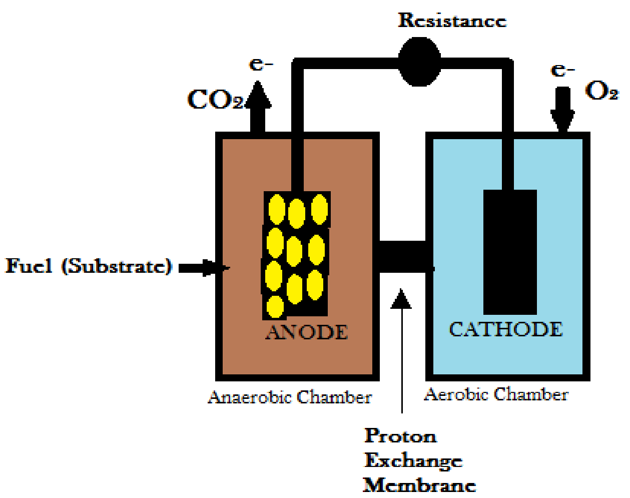

Figure 1. Schematic of a dual chamber microbial fuel cell

Massive attention is being given to this technology as a novel approach aimed at bioelectricity production along with simultaneous wastewater treatment [10,11]. MFC may be best described as a bioreactor, where microbes act as biocatalyst in metabolizing the organic substances containing the organic carbon to generate electricity [12, 13].

The aim of this research is to take the inward assents of waste materials, like molasses and kitchen household waste using double chamber MFC for electricity generation and thus help in waste disposal. The gains to be made from doing this are that MFCs are a very clean and efficient method of energy production.

II. MATERIALS AND METHODS

Setting up the MFC

The dual chambered MFC was setup using readily available materials, two transparent polyacrylic plastic containers with lid having a capacity of one litre, two PVC pipes with coupler, Aluminium mesh, Paper clips, Copper wire, Electrical tape, Duct tape, Milli voltmeter and Egg shell membrane as a proton exchange membrane (PEM) [14].

A hole was drilled for copper wire on the lids of containers. In the anode chamber, holes were drilled for the sampling to be done at intervals and one small hole for ventilation on the cathode chamber. One hole precisely of the size of a PVC pipe was drilled on one side of both containers for the salt bridge. Electrodes were prepared by folding aluminum mesh a few times over and bound with large paper clips. Ends of the copper wire were stripped and attached to both electrodes. Copper wire was inserted into the drilled holes on lids and the holes were sealed with electrical tape. The copper wires were attached to a millivoltmeter to detect the potential difference that will be established in the MFC (Figure 2).

To prepare the salt bridge, two PVC segments were fed through the holes in the sides of the chambers and secured using tape and a bonding material like Bondtite to form a watertight seal. The egg shell membrane (PEM) was stretched over one end of the PVC segment and then both segments were attached to each other using the coupler, thus locking the PEM in place.

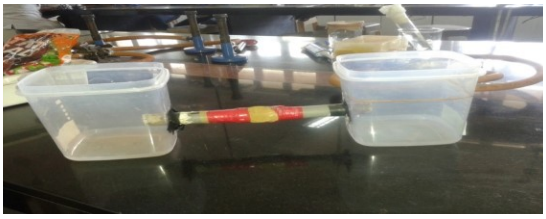

Figure 2. The Chambers Connected with the Salt Bridge

Organic raw material

The organic waste matter used for this work was molasses which was obtained from a local sugarcane juice centres in Kalyan and kitchen waste (orange peels, banana peels, vegetable peels, leftover vegetables etc.) which was obtained from a number of households.

The organic waste was blended properly in a mixer by adding water. A slurry was formed of proper consistency and poured into the anode chamber. The chamber was filled with the slurry till the brim. The pH of the slurry was checked. Samples were taken for organic matter content [15] and BOD [16]. The electrodes were submerged in the respective chambers and the lids were closed. The anode chamber was made airtight. The bacteria in the anode chamber were exposed to as little oxygen as possible. The bacteria present intrinsically in the organic waste were used for this MFC operation, thus no external inoculum was added. The collected samples were subjected to BOD and organic matter content analysis to calculate the performance of the MFC with respect to waste treatment. This analysis also estimated the effect of the different waste content, as molasses largely contains sucrose as its substrate whereas kitchen waste will contain a more diverse nature of organic matter.

III. RESULT AND DISCUSSION

Performance of MFC

The performance of the MFC was analyzed by observing the readings on the millivoltmeter which showed the potential difference established between the two electrodes and thus, the current established. The anode chamber was maintained in anaerobic conditions.

As it can be observed from the readings, the electricity output of the MFC increased with time for 4 days after the beginning of the operation of MFC. But after 4 days, the electricity output decreased until the 7th day (Figure 3, Figure 5). In their research, Moqsud *et al.,* (2013) [8] have gone on record and have had similar results regarding the current output in their MFC using organic waste. In their research, the current output increased for the first week, reached a peak and then it gradually decreased.

This decrease in current output maybe attributed to the decrease in organic matter, as the organic matter gets used up by the microbes present in the waste. As the organic matter serves as the food for the microbes in the MFC, their respiration rate will decrease as the organic matter decreases. This will in turn cause less electrons and protons to be produced and thus less current output.

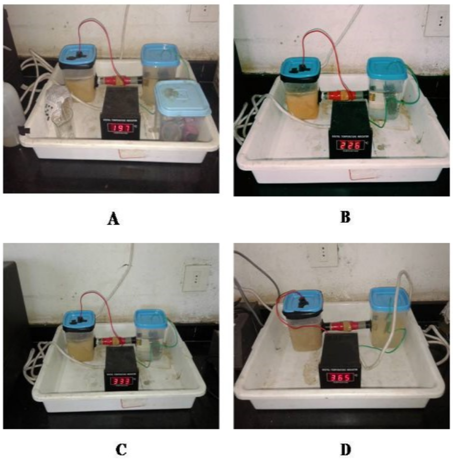

Figure 3. Milli voltmeter readings at different time intervals. (Molasses)

Kitchen Waste:

The kitchen waste (orange peels, banana peels, vegetable peels, leftover vegetables etc.) was taken for the MFC operation and blended well to form a slurry and poured into the anode chamber. The milli voltmeter readings were taken over a period of 7 days. The conditions were maintained identical as when the MFC was operated using molasses. The kitchen waste also has a large amount of organic matter.

The electricity output increased gradually until the 4th day, similar to the case when the MFC was operated with molasses. But the peak of the electricity output was not as high as molasses. After the 4th day, the electricity output gradually decreased until the 7th day (Figure 4, Figure 5). Moqsud *et al.,* (2013) [8] work on a MFC operated using kitchen garbage had similar results with respect to the trends of the electricity output. In their research they have reported that the organic waste of can be recycled as Bio-electricity generation. The MFCs by using the kitchen garbage is proved to be a good way to green electricity generation as well as the recycle of organic waste to maintain the healthy and pollution free environment. The by-product of the electricity generation in MFC by composting method can be used as soil conditioner after further treatment which is another way to serve agricultural based countries.

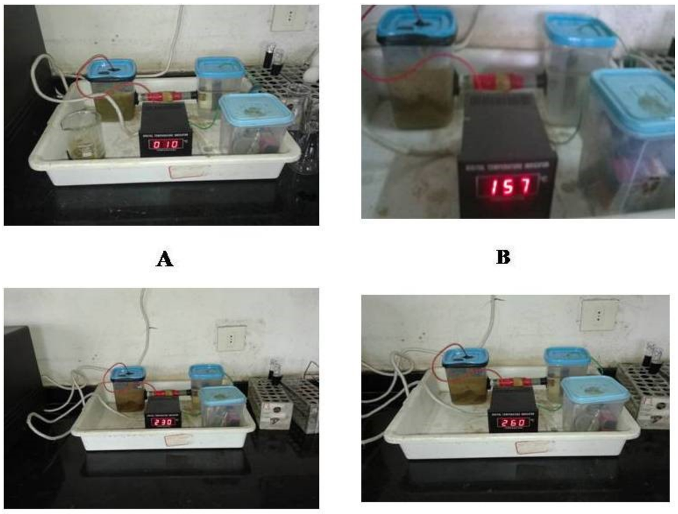

Figure 5. Millivoltmeter readings over the period of 7 days for MFC with kitchen waste

BOD analysis [16] of molasses and kitchen waste showed that the BOD of the sample decreased from day 1 to day 7 (Figure 6). A decrease of 54.55% was observed in molasses while only 5.7% decrease was seen in kitchen waste. It has been observed that the BOD of the sample decreases over a period of time with MFC operation. Ghangrekar and Shinde (2003) [17] have reported in their research that the MFC demonstrated its effectiveness for the treatment of wastewater with BOD removal of about 90%. Most pristine rivers have BOD of less than 2ppm. Although, such low BOD is almost impossible to achieve in wastewaters, it is of a very high significance that we are able to lower the BOD using MFCs. The BOD of untreated sewage varies, but averages around 600 ppm [18]. Thus, the results that have been achieved in this work are promising as the BOD of the waste water was almost halved. Although the BOD removal was low in the kitchen waste, it is a promising aspect as the MFC worked on kitchen waste from homes with no externally added components.

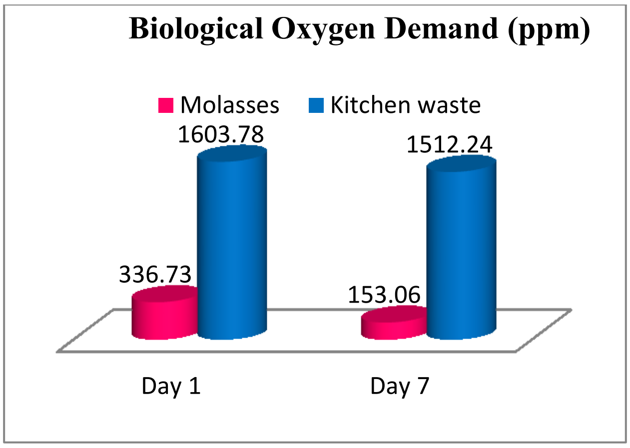

Figure 6. Comparison of BOD levels of molasses and kitchen waste after using in MFC

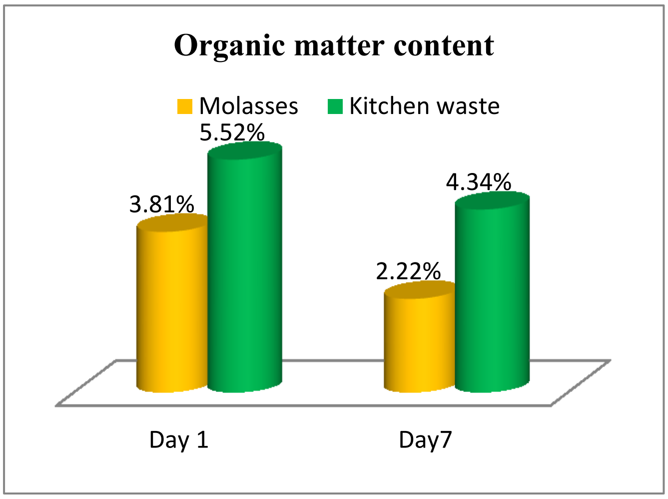

Figure 7. Comparison of organic matter content of molasses and kitchen waste after using in MFC

The organic matter content [15] of the sample decreased over the period of 7 days of the MFC operation. The percent decrease was 41.67% for molasses whereas for kitchen waste, the decrease was 21.31% (Figure 7). This was expected as the organic matter was being utilized by the microorganisms for their metabolism. This decrease in organic matter content also justifies the decrease in the current output. The depletion of organic matter proves that the MFC technology may be the potential answer for the wastewater treatment problem as it produces electricity simultaneously. As observed from the results, the kitchen waste powered microbial fuel cell did not show much decrease (21.31%) in the percent of organic matter. It might be the case that the microorganisms present intrinsically in the kitchen waste were not able to utilize the organic matter present in the kitchen waste.

The MFCs were considered to be used for treating waste water early in 1991 [19]. Municipal wastewaters, containing a multitude of organic compounds, could be used to fuel MFCs. The amount of power generated by MFCs in the wastewater treatment process can potentially halve the electricity needed in a conventional treatment process that consumes a lot of electric power aerating activated sludges. Furthermore, organic molecules such as acetate, propionate, butyrate can be thoroughly broken down to CO_2 and H_2O. MFCs using certain microorganisms have a special ability to remove sulfides as required in wastewater treatment [20].

The available sources of organic matter and substrate probably change the type of microbial population in the organic matter after the working of MFC. Gram's staining before and after the MFC operation showed an overview of the microbial population in the organic matter. Gram staining of the molasses samples revealed that before the MFC operation the overall microbial population in molasses had Gram positive as well as Gram negative bacteria along with yeast. After 7 days of MFC operation, the Gram stain showed majority of Gram negative bacteria and the formation of biofilms. Similar case was seen in kitchen waste. On 7th day, Gram negative bacteria were the majority. The bacterial community at the anode is mainly affected by the type of substrates used and ultimately influences the current generation [21]. Also, it is important to know that there are a number of bacteria in MFCs which may not be directly involved in the current production. Instead, they are involved in the degradation of complex organic substrates to simpler ones which are then used by exoelectrogens [22].

IV. CONCLUSION

The organic waste can be recycled as Bio-electricity generation. The MFCs by using the kitchen garbage has proved to be a good way to green electricity generation as well as the recycle of organic waste to maintain a healthy and pollution free environment. Many works in this field have reported that the by-product of the electricity generation in MFC by composting method can be used as soil conditioner after further treatment which is another way to serve the agricultural based country.

The maximum potential established was 365 mV in the case of molasses and 260mV in the case of kitchen waste. It is a common belief that the electricity output of a MFC depends upon the amount of organic matter present. But as observed in this work, the organic matter content was seen to be more in the case of kitchen waste with respect to molasses, but even then the electricity output was more in molasses powered MFC. As it is known that molasses contains a large amount of sucrose which forms the major part of its organic matter. Also, sucrose is utilized by many microbes readily. On the other hand, the organic matter in kitchen waste is not necessarily of one type, and it may have many different constituents which may hinder the growth of some bacteria. Overall, the performance of the kitchen waste powered MFC was not as good as molasses powered MFC. The BOD removal was minimal and so was the organic matter content lowering. The molasses powered MFC is a promising aspect as molasses is also a waste and is readily available. The kitchen waste MFC has to be further looked into as to find out what other factors might be affecting it. Parameters such as distance between the electrodes, surface area of the electrodes, catholytic composition, etc. need to be studied further to check the efficiency of the same.

V. REFERENCES

1. Chang I.S., Kim B.H., Lovitt R.W., Bang J.S. (2001) Effect of CO partial pressure on cell-recycled continuous CO fermentation by Eubacterium limosum KIST612.Process Biochem 37: 411-421.
2. Chang I.S., Jang J.K., Gil G.C., Kim M., Kim H.J., Cho B.W., Kim B.H. (2004) Continuous determination of biochemical oxygen demand using microbial fuel cell type biosensor. Biosens Bioelectron 19: 607-613.
3. Chang I.S., Moon H., Jang J.K., Kim B.H. (2005) Improvement of a microbial fuel cell performance as a BOD sensor using respiratory inhibitors. Biosens Bioelectron 20: 1856-1859.
4. Cheng X., Shi Z., Glass N., Zhang L., Zhang J , Song, D., Liu, *Z.*-S., Wang, H., Shen, *J.* (2004) A review of PEM hydrogen fuel cell contamination: Impacts, mechanisms, and mitigation. J Power Sources 165: 739-765.
5. Gong M., Liu X., Trembly J., Johnson C. (2007) Sulfur-tolerant anode materials for solid oxide fuel cell application. J Power Sources 168: 289-298
6. Kim I.S., Chae K.J., Choi M.J., Verstraete W. (2008) Microbial fuel cells: recent advances, bacterial communities and application beyond electricity generation. Environ Eng Res 13: 51-65.
7. Kim J.R., Min B., Logan B.E. (2005) Evaluation of procedures to acclimate a microbial fuel cell for electricity production. Appl Microbiol Biotechnol 68: 23-30.
8. Moqsud A.M., Omine K., Yasufuku N., Hyodo M., Nakata Y. (2013). Microbial fuel cell (MFC)

for bioelectricity generation from organic wastes.Waste Manage. 33:2465–2469.

9. Sharma Y, Li B. (2010). The variation of power generation with organic substrates in single-chamber microbial fuel cells (SCMFCs). Bioresour Technol. 101:1844–1850.
10. Sevda, S., Dominguez-Benetton, X., Vanbroekhoven, K., De Wever, H., Sreekrishnan, T.R., Pant, D. (2013). High strength wastewater treatment accompanied by power generation using air cathode microbial fuel cell. Appl. Energy 105, 194–206 doi:10.1016/j.apenergy.2012.12.037
11. Watanabe, K., (2008). Recent Developments in microbial fuel cell technologies for sustainable Bioenergy. Journal of Bioscience and Bioengineering, 106: 528-536.
12. Gil G.C., Chang I.S., Kim B.H., Kim M., Jang J.K., Park, H.S., Kim, H.J., (2003) Operational parameters affecting the performannce of a mediator-less microbial fuel cell. Biosens Bioelectron 18: 327-334.
13. Song C. (2008) Fuel processing for low-temperature and high-temperature fuel cells: Challenges and opportunities for sustainable development in the 21 st century. Catal Today 77: 17-49.
14. Du Z., Li H., 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
15. Walkley, A., 1947. A critical examination of a rapid method for determination of organic carbon in soils - effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 63: 251-257.
16. Winkler, L.W. (1888). Die Bestimmung des in Wasser gelösten Sauerstoffen. Berichte der Deutschen Chemischen Gesellschaft, 21: 2843–2855.
17. Ghangrekar M. M. and Shinde V. B. (2008) Microbial fuel cell for electricity generation and sewage treatment Water Science & Technology—WST 58.1
18. Shukla, A., Suresh, P., Berchmans, S. and Rajendran, A. (2004). Biological fuel cells and their applications. *Current Science*
19. Habermann, W. and Pommer, E.H. (1991) Biological Fuel Cells with Sulphide Storage Capacity. Applied Microbiology and Biotechnology, 35, 128-133. https://doi.org/10.1007/BF00180650
20. Rabaey K. and Verstraete W. (2005) "Microbial fuel cells: novel biotechnology for energy generation," Trends Biotechnology
21. Zhang Y., Min B., Huang L., Angelidaki I. (2011) Electricity generation and microbial community response to substrate changes in microbial fuel cell. Bioresour Technol 102:1166–1173
22. Patil S.A., Surakasi V.P., Koul S., Ijmulwar S., Vivek A., Shouche Y.S., Kapadnis B.P. (2009) Electricity generation using chocolate industry wastewater and its treatment in activated sludge based microbial fuel cell and analysis of developed microbial community in the anode chambe. Bioresour Technol 100:5132–5139.