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Role of Mediators in Microbial Fuel Cell for Generation of Electricity and Waste Water Treatment

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ABSTRACT

The development of Microbial Fuel Cell (MFCs) is important to the advancement of alternative fuels. Electricity can be produced using the degradation of organic matter by micro organism in MFC technology which may provide a new method to offset waste water treatment plant at an operating cost with continuous improvement in MFC, it may be possible to increase power and generation rate production. A bacterium in the anode compartment transfers electrons obtained from an electron donor (glucose) to the anode electrode. This occurs either through direct contact, nanowires, or mobile electron shuttles (small spheres represent the final membrane associated shuttle). During electron production protons are also produced. Thus, the combination of waste water treatment along with electricity production may help in saving millions of rupees as cost of waste water treatment at present. In the present investigation we used Mediators (Methylene blue and Neutral red) and filming electrodes as modified electrodes to increase power generation.

Key words: - Dairy waste water, Electricity generation, Filming graphite electrodes, Mediators etc.

[I] INTRODUCTION

Among electrochemical cells, MFCs are special types of biofuel cells; producing electric power by utilizing microorganisms [4] .The microbial fuel cell uses hydrogen fuel and oxygen to produce electricity. MFC converts organic matter into electricity by using bacteria as biocatalyst. [1,2 3,] The conventional MFC is a two chamber system, consisting of anode and cathode that is separated by a proton exchange material .This system has been half biological, because only the anode side contains electrochemically active microorganisms. While the cathode is abiotic. The microorganisms function as biocatalysts, motivating the degradation of organic materials to produce electrons, which travel to the cathode side via an electric circuit. The presence of free electrons on the cathode of MFCs initiates a reduction of oxygen to produce water [4]. In

biological fuel cells, the catalyst is either microorganisms as simple as Baker's yeast or an enzyme. Biological fuel cells convert the chemical energy of carbohydrates, such as sugar and alcohol directly into electric energy. As most organic substrates undergo combustion with the evolution of energy [5] Recently, efforts have been made to treat domestic waste water using MFC and simultaneously to produce electricity due to environmental concerns and the need to reuse waste [5,6]. Anaerobic sewage sludge is provide as good candidate for inoculating a MFC as it is easily obtained from a waste water treatment plant and it contains highly varied bacterial communities that contain electrochemically active strains of bacteria [7]. MFCs have operational and functional advantages over the technologies currently used for generating energy from organic matter [8].
The development of MFC is, however, still in it's infancy with the need of considerable improvements with respect to power output and accessible substrates. Thus, most MFCs still require their fuel to be of low molecular nature. The majority of herbal biomass however consists of macromolecular compounds including complex carbohydrates like starch and cellulose [11]. The direct oxidation of microbial hydrogen shows a number of potential advantages, Thus, it does not require the separation and purification of the gas for it's subsequent conversion in conventional fuel cells .MFCs shows promise as a method to treat waste water and to produce electricity at the same time [9,10,13].
The aim of the present study was to investigate the disposal of dairy waste with MFC and simultaneously exploiting dairy waste for microbial electricity generation, we demonstrate culture and Activated sludge containing hydrogen producing microorganisms can in fact serve as a medium in MFCs. Since the performance of MFC, depends on the nature of microbes, we have attempted the variety of cultures in MFCs such as activated sludge from dairy waste plant, The performance of MFC formed with dairy waste is studied and the suitable culture with maximum performance of MFC is revealed.

[II] MATERIALS AND METHODS

2.1 Inoculum sources

The performance of MFC was studied for different electrolytes and cultures of the microbes (*Lactobacillus)* collected from, Activated sludge from waste water plant (Gokul dairy waste water, Kolhapur)

2.2Mfc Construction

Two chamber air cathode MFC was constructed in our laboratory as shown in figure 3. The MFC consisted of two vessels (1000 ml capacity) with graphite electrodes (12 x 1.2. cm) The vessels were joined by a salt bridge. Anode chamber was filled with dairy waste and culture, while the cathode was filled with 1 N potassium ferricyanide /KOH solution as an electrolyte where air was provided using air sparger. The anode chamber was stirred with magnetic stir bar and operated at room temperature (30^{o}C).The electrodes were attached using copper wire with all exposed metal surfaces sealed with a non-conductive material (M-seal).

2.3 Analysis

The voltage (V) across an external resistor (1000Ω) in the MFC circuit was continuously monitored (30 mint. intervals) current (I) and Power output were calculated.

[III] RESULTS AND DISCUSSION

3.1 MFC with dairy waste

The electrical generation in MFC by using microbial culture with dairy waste has been studied by employing a fuel cell geometry designed and fabricated in our laboratory. The open circuit voltage of the MFC was measured for about 24 h. The variation of Voc with time is shown in graph 1,2 for cells formed with the series of electrodes and presence of mediaters, Microbes. It is seen that the Voc increases with time sharply, at the beginning, attends the maximum value and then decreases slowly. This behavior of Voc with time‘t’ is attributed to the rate of utilization of dairy waste by microbes. The origin of voltage in MFC can be understood by considering the chemical reactions occurring at cathode and anode compartments given as follows.

At anode: $C_6H_{12}O_6 + 6H_2 \rightarrow 6CO_2 + 24\,H^+ + 24\,e^- + E_0 = 0.014$ V ….. (1)

At cathode: $6O_2 + 24\,H^+ + 24\,e^- \rightarrow 12H_2O + E_0 = 1.23$ V …….. (2)

Considering the above two reactions the maximum open circuit voltage expected theoretically for MFC is of the order of 1.216 V. However, in the present investigation the value of Voc observed is comparatively smaller than theoretical value 0.91 V Table 4. This lower value is attributed to the number of factors consisting of the voltage drop (loss) across the salt bridge, the nature of microbes, the interphase between microbes and electrodes and the transport mechanism of charge from microbes to the electrode etc.

The magnitude of open circuit voltage was found to be different for the cells formed with different electrolyte surface area of electrode. The MFC system formed with series shows the maximum Voc of the order of 1.88 V. Whereas the lowest value of Voc in the MFC cell formed without mediator is of the order of 0.91V. As shown in Table No. 5. The maximum value of Voc is attributed in series of electrodes, and presence of mediators.

3.2 DISPOSAL OF DAIRY WASTE

The chemical and physical properties of dairy waste were measured before and after the treatment with MFC. It has been observed that the MFC has decreased the COD value of dairy waste from 300 to 166 mg/l. Similarly the BOD has also been decreased from 400 to 150 mg/l. The pH of the dairy waste was measured before and After MFC and found to change from initial value of 4 to 6.The above observations indicates that the MFC technique can be potential method for disposal of dairy waste in view of the environmental protection. In conclusion treatment of diary waste with MFC helps to both produce electricity and dispose of dairy waste.

3.3 Electrodes

Fig.1: Graphite electrodes connected with wire.

Graphite plates are used as electrodes and they are externally connected with wires.

Sample of dairy waste water was collected from Gokul Dudh Utpadak Prakriya Ltd., Kolhapur.

Fig.2: Isolated colonies on MRS agar in petri plates

By using selective media i.e. MRS agar, we were isolated colonies of lactobacillus.Salt bridge formation was done by using mixture of 2-5 % agar in 1M KCl and stored in the refrigerator.

3.4 CONSTRUCTION OF MFC IS GIVEN BELOW

Fig.3: Experimental setup of MFC

By using two compartments i.e. anode and cathode which were connected with salt bridge and also with voltmeter as well as ammeter. In this way construction of MFC was done.

3.5 Filming on electrode

Fig.4: Electrode after filming

Filming was done by equally spreading media on the electrode.

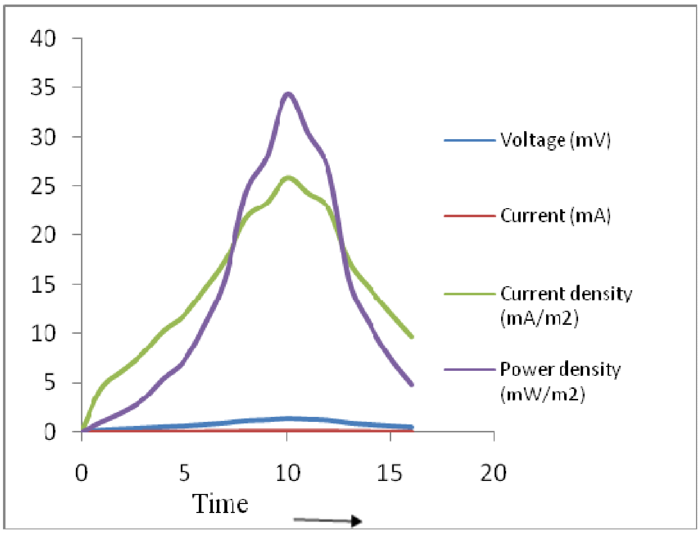
EXPERIMENT NO. 1

Anode chamber: Dairy waste 900ml, Inoculum 100ml

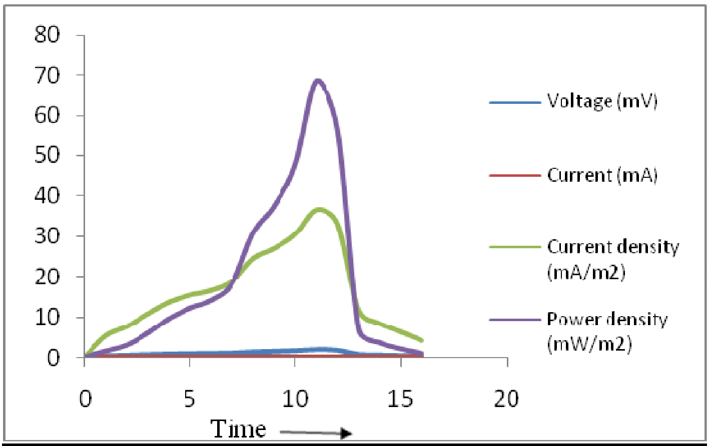
Micro organism: Lactobacillus   Mediator: Methylene Blue

Cathode Chamber: 1 N KOH 1000ml   Electrode: Graphite plate with filming on anode

Resistor: 10 Ω ,Aeration was given to Cathode compartment and Stirring was done by Magnetic stirrer in Anode compartment.



Graph 1 Results of MFC by using KOH electrolyte & Methylene Blue as mediator also use filming electrode



Graph 2: Results of MFC in series

[Iv] Comparative Study: Results Obtained Without Filming On Anode or By Using Simple Electrodes

This result was obtained by using series arrangement. In this two Anode chambers were used and only one cathode chamber was present.

Electrolyte	Mediator	Voltage (mV)	Current (mA)	Current density (mA/m^2)	Power density (mW/m^2)
KOH	Without Mediator	0.68	0.068	13.229	8.996
KOH	Methylene Blue	0.76	0.076	14.785	11.237
KOH	Neutral Red	0.67	0.067	13.035	8.733
Potassium Ferricynide	Without Mediator	0.67	0.067	13.035	8.733
Potassium Ferricynide	Methylene Blue	0.73	0.073	14.203	10.367
Potassium Ferricynide	Neutral Red	0.69	0.069	13.424	9.262

Table 3: Results obtained without filming on anode or by using simple electrodes

MFC was done by using different electrolytes and also with and without mediator. Here, as compare to Neutral red mediator and without mediator, methylene blue shows highest voltage.

4.1results Obtained With Filming On Anode

Electrolyte	Mediator	Voltage (mV)	Current (mA)	Current density (mA/m^2)	Power density (mW/m^2)
KOH	Without Mediator	0.91	0.091	17.704	16.110
KOH	Methylene Blue	1.33	0.133	25.875	34.414

Table 4: Results obtained with filming on anode

Filming was done on electrode. Readings were obtained by using with or without mediator. The obtained results were higher than without filming.

4.2 Results obtained in MFC Arranged in Series

Electrolyte	Mediator	Voltage (mV)	Current (mA)	Current density (mA/m^2)	Power density (mW/m^2)
KOH	Without Mediator	1.88	0.188	36.575	68.762

Table 5: Results obtained in MFC arranged in series

4.3 Chemical Analysis

Sample	Before Electricity generation mg/lit	After Electricity generation mg/lit
Dairy Wastewater COD	300	166
Dairy Wastewater BOD	400	150

Table No. 6: COD & BOD Results

[V] CONCLUSION

Isolation of micro-organisms from dairy whey was done.The generation of electricity was done by using isolate.Electricity was generated by using dairy whey in anode compartment and electrolytes in cathode compartment.When mediators were used more electricity was generated as compare to mediators were not used.In mediators also, methylene blue were used, more electricity was generated as compare to Neutral red.By using electrode with filming, the highest results were obtained.MFC arranged in series shows maximum readings.

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REFERENCES:

1. Suzuki S.,Karube I, and Matsunaga T,.1978.Applications of biochemical fuel cell to waste water.Biotechnology Bioengineering symp.,8,501-511.

1. Bond D.R. and Lovley D.R., 2003. Electricity production by *Geobacter sulfurrreducens* attached to electrodes. Applied and Environmental Microbiology, 69, 1548-1555.
2. Wingard L.B., Shaw C.H. and Castner J.F., 1982. Bioelectrochemical fuel cells. Enzyme and Microbial Technology, 4(3), 137–142.
3. Zhen H., Largus T.Angenent, Application of bacterial biocathodes in microbial fuel cells, (2006) Electroanalysis ,19-20:2009-2015.
4. Shukla A. K,.Suresh P, Berchmans S., Rajendran A.,Biological fuel cells and their applications,(2004) Current science,87:4
5. Logan B.E., 2004 Feature article:Biologiacally extracting energy from waste water:biohydrogen production and microbial fuel cells.Environmental science and Technology, 38,160-167.
6. Raekim J., Booki M., Bruce E.,Logan, Evaluation of procedures to Acclimate microbial fuel cell for electricity production(2005), Applied MicrobioTechnol,68:23-30.
7. Rabaey K.I. Verstraete W, Microbial fuel cells:novel biotechnology for energy generation,(2005) Trends in Biotechnology,23:6.
8. Niessen J.,.Schroder U, Scholz F., Exploiting complex carbohydrates for microbial electricity generation- a bacterial fuel cell operating on starch, (2004) Electrochemistry Communications, 6:955-958.
9. Lovely D.K., Microbial fuel cells: novel microbial physiologies and engineering approaches, (2006) Current option in Biotechnology, 17:327-332.
10. Niessen J.,.Schroder U, Harnisch F. and Scholz F.,Gaining electricity from in situ oxidation of hydrogen produced by fermentative cellulose degradation, (2005) Letters in applied microbiology, 41:286-290.
11. Rosenbaum M., Schroder U., Scholz F., In situ electrooxidation of photobiological hydrogen in a photobioelectrochemical fuel cell based on Rhodobacter sphaeroides, Environmental science and Technology,20:
12. Zhen H., Shelley D., Minteer, Largus T. Angenent, Electricity generation from artificial; waste water using an upflow microbial fuel cell, (2005), Environmental science and Technology, 39:5262-5267