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Mediatorless Microbial Fuel Cell with Nafion-115 and Salt bridge as Proton Exchange Membrane

KEYWORDS: Microbial Fuel Cell, Proton Exchange Membrane, Salt bridge, Voltage.

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ABSTRACT *A double chambered microbial fuel cell with slaughter house waste water as a substrate was optimized in terms of various operating conditions. The study was carried out using both salt bridge and Nafion-115 membrane as proton exchange system. The dependence of power output on operating conditions like time, pH, temperature and kinds of electrode was also investigated. The voltage produced in the MFC was found to increase linearly with time. The maximum voltage of 0.5V was observed in the MFC setup where Nafion-115 membrane was used with carbon rod as the electrodes, at the pH of 7.3 and at the room temperature of 30oC. With salt bridge as proton exchanger, the output voltage was observed to be only 0.22V. Hence mediatorless MFC operating at ambient conditions with Nafion-115 is emphasized as the eco-friendly model for bioelectricity generation and slaughter house wastewater treatment.*

1. INTRODUCTION

Renewable bio-energy is viewed as one of the ways to alleviate the current global warming crisis. Major efforts are devoted to develop alternative electricity production from renewable energy sources without carbon dioxide emission[1]. Microbial Fuel Cell (MFC), a novel method of directly generating electricity from organic matter in waste water, simultaneously treating waste water solves issues of energy crisis and environmental damage. MFC is a bio-electrochemical system exploiting bacterial oxidation of biodegradable organic matter, to generate electricity. The power production in the MFC mainly depends on the reactor configuration, electrode material, performance of proton exchange membrane (PEM), specific source of substrate and operating conditions such as temperature and pH. The microorganism present in anode chamber of fuel cell acts as catalyst to convert chemical energy in waste water to electrical energy. The microbial metabolism generates electrons and protons by oxidation of organic substrate, which lead to the development of bio-potential. The electrons transferred to the anode by the bacteria through various mechanisms such as solid conductive matrix or by electron shuttles. Electrons are then transferred to external circuit. The anodes of microbial fuel cells behave as bacteria's typical electron acceptor and thus the movement of the electrons to the cathode of MFC through a resistor, generate electricity. Many improvements are being carried out to enhance the power production level of MFC [1 - 13].

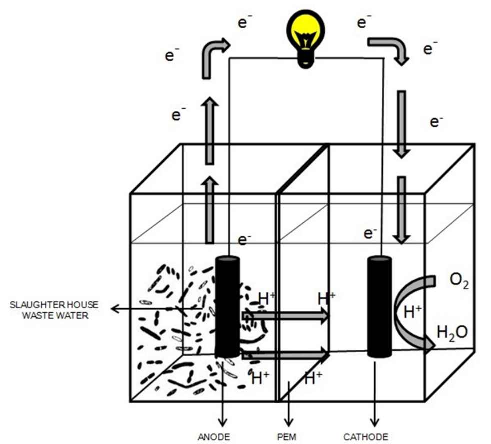

Fig. 1. Schematic diagram of typical MFC with Proton Exchange membrane(PEM) using slaughter house waste water.

The wastewater from the slaughter house constitutes significant environmental and public health hazards and environmental pollution. Pathogens present in animal carcasses or shed in animal wastes are reported as rotaviruses, hepatitis E virus, Salmonella spp., E. coli O157:H7, Yersina enterocolitica, Campylobacter spp., Cryptospordium parvum and Giardia lamblia[10,14]. As the wastewater contains many bioorganic materials which helps to grow the microorganism, it can be used to generate bioelectricity by MFC mechanism. Hence in the present study, an attempt has been made to explore the application of slaughter house wastewater in MFC for harvesting bio-electricity, to optimize the conditions for efficient and sustained electricity production and to design an eco-friendly wastewater treatment process.

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2. EXPERIMENTAL METHODS

The slaughter house wastewater collected from nearby market was used as substrate in MFC models. No additional nutrients were given for micro-organisms except the nutrients present in the wastewater. The study was carried out using both salt bridge and Nafion-115 membrane as proton exchange system in a two-chambered MFC models. To identify the optimized conditions for enhanced electricity generation. The experiment was carried out by using different electrodes [carbon rod - 6cm×5mm(C.R), graphite rod - 6cm×3mm (G.R) and stainless steel - 6cm×10mm (S.S)][15-20]. The effect of operating conditions such as time (half an hour interval up to 7 hours), pH (1 to 14) and temperature (30°C to 55°C) on the efficiency of MFC was also studied. The output of the MFC was monitored using a multimeter (MASTECH M-830B).

Two MFC models were setup in the present work – mediatorless MFC with Nafion-115 membrane and Mediatorless MFC with salt bridge.

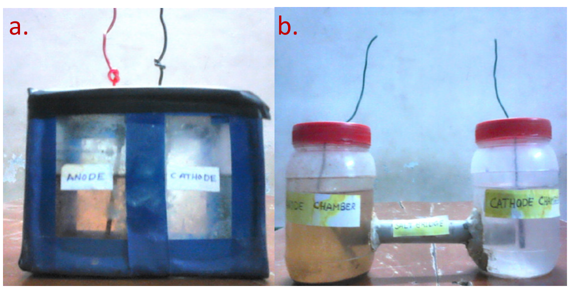


Fig. 2. a) Double Chambered MFC with Nafion-115 membrane. b) Double Chambered MFC with Salt bridge.

Double chambered MFC with Nafion-115 membrane was constructed using glass with the dimension of 10cm×6.5cm, with the proton exchange membrane in the middle of the anodic and cathodic chambers [1, 21]. MFC with salt bridge was constructed by using two separate anodic and cathodic chambers connected by PVC pipe (10cm), filled with 5% agar in 1M KCl. In order to maintain an anaerobic condition, the chambers were tightened with the help of lids. The MFC setup with Nafion-115 membrane was filled with 150ml of slaughter house wastewater and 150ml of double distilled water in the anodic and cathodic chambers respectively, in which the electrodes were immersed and connected to the multimeter. The same procedure was followed in other MFC model.

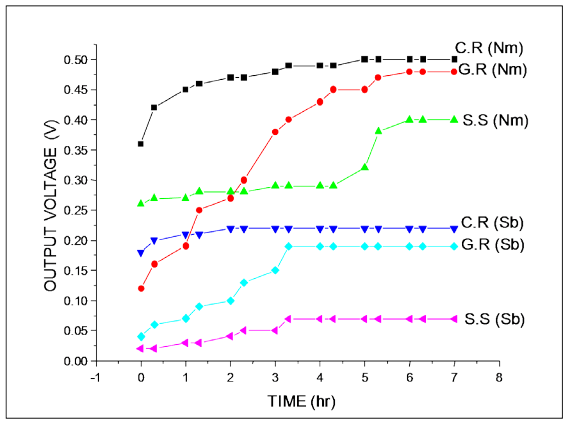
3. Results and Discussion

3.1. Mediatorless MFC

The study of mediatorless MFC with Nafion-115 membrane and salt bridge (Table1, Fig. 3) proved that the efficiency is more when Nafion-115 is used as Proton Exchange Membrane since Nafion-115 is more permeable with lower resistance than salt bridge. To determine the optimum conditions, the output voltage was measured at various time intervals, pH and temperature using all the three electrodes (C.R, G.R and S.S). In both the models, the output voltage increased with time and attained after 2-6 hrs. On comparing the efficiency of the three electrodes used in MFC, C.R was found to be more effective as it has high surface area with high porosity that prevents clogging and favouring oxygen transfer towards its surface[11,12]. Moreover it is conductive, biocompatible, inexpensive, chemically stable and easy to handle in the reactor solution. As C.R showed better efficiency, it was used in further studies.

Table 1. Efficiency of Mediatorless MFC with different electrodes (T=30˚C, pH=7.3).

TIME (hr)	OUTPUT VOLTAGE (V)					
	MFC with Nafion-115 membrane			MFC with Salt bridge		
	C.R	G.R	S.S	C.R	G.R	S.S
0.00	0.36	0.12	0.26	0.18	0.02	0.04
0.30	0.42	0.16	0.27	0.20	0.02	0.06
1.00	0.45	0.19	0.27	0.20	0.03	0.07
1.30	0.46	0.25	0.28	0.21	0.03	0.07
2.00	0.46	0.27	0.28	0.21	0.04	0.09
2.30	0.47	0.30	0.28	0.22	0.05	0.10
3.00	0.47	0.38	0.29	0.22	0.05	0.13
3.30	0.48	0.40	0.29	0.22	0.05	0.15
4.00	0.49	0.43	0.29	0.22	0.07	0.19
4.30	0.49	0.45	0.29	0.22	0.07	0.19
5.00	0.49	0.45	0.32	0.22	0.07	0.19
5.30	0.50	0.47	0.38	0.22	0.07	0.19
6.00	0.50	0.48	0.40	0.22	0.07	0.19
6.30	0.50	0.48	0.40	0.22	0.07	0.19
7.00	0.50	0.48	0.40	0.22	0.07	0.19



Nm- Nafion membrane, Sb- Salt bridge

Fig. 3. Effect of Mediatorless MFC with Nafion -115 membrane and salt bridge

3.2. Effect of Time and nature of Electrode

The output voltage recorded at various time intervals using all the electrodes in the MFC models with Nafion-115 membrane suggested that, there was a slight increase in the output voltage up to 5 hours when C.R was used, after which it attained saturation . While in other electrodes, the saturation was reached at the maximum of 6 hours .On the other hand in MFC with salt bridge, output voltage was much lower for all the electrodes with the saturation time of 2 – 4 hours (for MFC with CR electrode the output voltage 0.22V for Salt bridge, 0.5 V for Nafion-115). Since no desired effect of proton exchange was observed using salt bridge, the operation of MFC with salt bridge is considered as less effective.

3.3. Effect of pH

The slaughter house wastewater had the initial pH of 7.3. To determine the optimum pH for maximum electricity generation, the pH variation was done in the range of 1 to 14. The data in Table 2 and Fig.4 shows that the output voltage increased up to pH 7 and then decreased. It clearly emphasized the effective operation of MFC at ambient conditions (i.e.) at about neutral pH 7.3, indicating the eco-friendly wastewater treatment process without secondary pollution (Fig.4).

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Table 2. Effect of pH on Mediatorless MFC with Nafion -115 membrane and Salt bridge.

pH	OUTPUT VOLTAGE (V)	
	MFC with Nafion-115 membrane	MFC with salt bridge
1	0.03	0.02
2	0.04	0.02
3	0.07	0.04
4	0.08	0.07
5	0.11	0.12
6	0.24	0.17
7	0.42	0.20
8	0.35	0.18
9	0.34	0.17
10	0.33	0.14
11	0.20	0.11
12	0.18	0.05
13	0.07	0.02
14	0.02	0.02

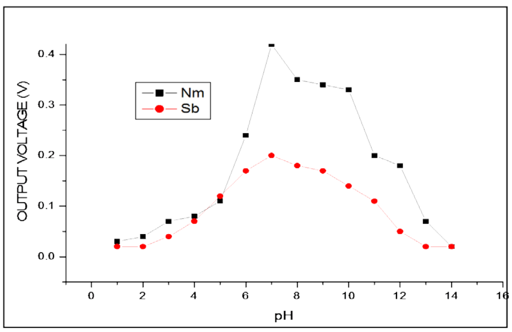

Fig. 4. Effect of pH on Mediatorless MFC with Nafion-115 membrane and Salt bridge.

3.4. Effect of Temperature

To study the effect of temperature on microbial oxidation for the generation of electricity, the temperature was varied in the range of 30, 35, 40, 45, 50 and 55°C (Table 3, Fig. 5). The analysis proved that the output voltage increased from 30°C to 45°C and decreased at higher temperature, revealing the fact that bio-catalyzed electrolysis is hindered at higher temperature. Since the optimum temperature for effective bio-electricity generation is identified in the range of 30°C to 45°C, the MFC model designed in the present study is practically proved to be more effective at room temperature.

Table 3. Effect of Temperature on Mediatorless MFC (Electrode=C.R, pH=7.3, t=30min.).

T (C)	OUTPUT VOLTAGE (V)	
	MFC with Nafion-115 membrane	MFC with Salt bridge
30	0.42	0.18
35	0.42	0.19
40	0.44	0.20
45	0.45	0.21
50	0.36	0.19
55	0.24	0.16

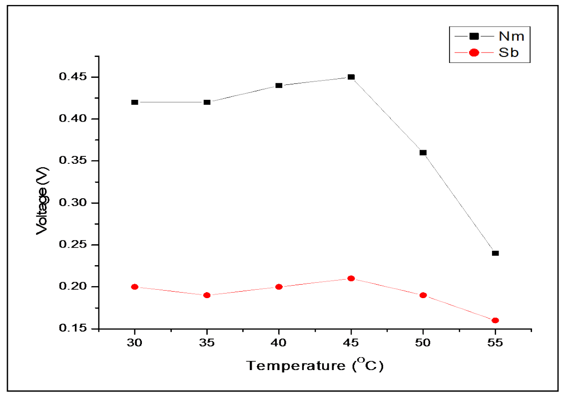

Fig. 5. Effect of Temperature on Mediatorless MFC (Electrode=C.R, pH=7.3, t=30min.).

4. Conclusion

In the present work, two models of double-chambered mediatorless MFCs with proton exchange membrane Nafion-115 and Salt bridge were designed and were found to be efficient in the maximum output voltage was recorded to be 0.5V at the pH of 7.3 at ambient conditions suggesting a green technology for power generation and wastewater treatment. Power generation even in the absence of mediators the analytical data revealed that the double – chambered Mediatorless MFC with Nafion-115 as proton exchange membrane is more effective for practical applications such as bio-electricity generation and wastewater treatment due to easy scale-up, eco-friendliness, cost effectiveness, reduced operational conditions, accelerated oxygen diffusion and direct electron transfer to anode.

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