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Short communication

A comparative study of a bio fuel cell with two different proton exchange membrane for the production of electricity from waste water

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Abstract

In the present study, electricity generation with waste water as substrate was investigated in a two compartment biofuel cell with two different combinations of electrodes and membrane. Two proton exchange membranes namely nafion and agar salt bridge and aluminum as electrode were used in the biofuel cell. It was found that biofuel cells operated with nafion produce maximum voltage 0.504 V with a current density of 0.1 A/m^2 whereas in case of agar salt bridge maximum voltage of 0.145 V with a current density of 0.05 A/m^2 was obtained. The more voltage produced in case of nafion is attributed to its low resistance for hydrogen ion transport.

Keywords: Biofuel cell; Proton exchange membrane; Nafion; Aluminium electrode

1. Introduction

Today's energy intensive world is mostly dependent on the ephemeral deposits of fossil fuels to meet its ever-growing energy demand. The sources of fossil fuels are limited and are being depleted very rapidly. Another problem associated with the use of fossil fuel is production of large amount of waste during its conversion into energy. The above problems associated with use of fossil fuel may result into energy insecurity in the future. This energy insecurity problem can be eliminated using green sources of energy. In microbial fuel cells (MFC) chemical bonds of organic wastes are directly converted into current through enzymatic reactions of microorganisms under anaerobic conditions [1–3]. In the MFCs the waste is also treated along with production of electricity and thus it is a futuristic novel eco-friendly technology which has potential to supersede the traditional waste reduction technologies such as adsorption, absorption etc [4–8].

Presently, low efficiency of MFCs is measuring to be a challenge for its emersion as a viable commercial technology. In order to increase the MFC efficiency, several factors associated with MFC operation and components such as the type of biocatalysts, membrane (electrolyte) or separators, temperature, pH, substrates, the type and materials of electrodes, electrode catalysts, cell configuration and architecture etc. have been the subject of intensive research [9–15].

Proton exchange membrane is used to separate the aerobic and anaerobic chambers in MFCs and plays the most vital role because it acts as hydrogen ion transporter from the anaerobic to the aerobic chamber to maintain electrical neutrality. Different researchers have used various types of proton exchange membrane but nafion is of prime importance because of its thermal and mechanical stability and low resistance to cation transport with its high cost as its only major drawback [16,17]. So, in order to find an alternative of the Nafion 117, several polymeric membranes such as ultrafiltration and microfiltration membranes, sulphonated polyether ether ketone membrane, anion and cation exchange membranes, bipolar membrane, and forward osmosis membranes have been studied [15–18].

The above discussion shows that there is a lot of scope of working in this area with the objective of increasing the efficiency and reducing the cost of MFCs. Keeping the important challenges in mind the present work is focused on the use of cost effective proton exchange membrane (agar salt bridge) in MFCs and compare its performance with nafion as membrane under similar operating condition.

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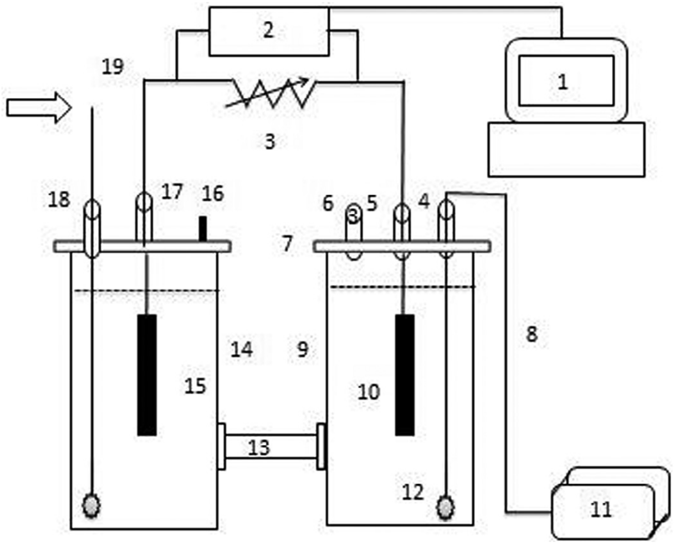

Fig. 1. Schematic diagram of microbial fuel cell. 1. Computer, 2. Multi-meter, 3. Variable external resistance, 4. Bore for air sparging, 5. Bore for passing electrode, 6. Bore for excess air exit, 7. Compartment lid, 8. Plastic tube for air sparging, 9. Cathode compartment, 10. Cathode, 11. Air pump, 12. Spherical ceramic, 13. Separator for salt bridge/nafion, 14. Anode compartment, 15. Anode, 16. Sampling bore, 17. Bore for passing electrode, 18. Bore for N_2 sparging, 19. Electrical wire.

2. Materials and methods

2.1. Biofuel cell construction

MFC was constructed with two cylindrical plastic compartments of equal dimensions with working volume of 2 L. The two compartments were connected by a separator (2.54 cm diameter, 10 cm length) in which agar salt and nafion were used as proton exchange membrane. Agar salt bridge was prepared by 3% agar and 1 M KCL and nafion was procured from Vinpro Tech, Hyderabad, India. Aluminum mesh (5 × 5 cm) was used as electrode. The compartment that functioned as the anode chamber was sealed with a parafilm to maintain anaerobic conditions. The other compartment, which was used as a cathode chamber, was filled with 2 L of distilled water. A small aquarium air pump was used to aerate the cathode chamber to maintain aerobic condition (Fig. 1). Before starting the experiments, Nitrogen gas was sparged in to the anodic chamber in order to create an anaerobic condition. Variable resistance box (40 ohm to 1000 ohm) was connected in the circuit of MFCs to measure potential drop. The current generated was measured using a digital multi-meter (MASTECH ms8340B) which is connected to the computer for data recording.

2.2. Inoculation and culture maintenance

Mixed bacterial culture was used as inoculum obtained from anaerobic digester tank of sewage treatment plant Bhagwanpur, Varanasi, India. The *Geobacter sp.* medium was used for growth and maintenance of culture as given in Table 1 and Table 2 [10,19]. In the experiment, waste water along with 5% glucose (as carbon source) was used as feed for growth of bacteria [19–21].

Table 1
Medium specific to *Geobacter sp. (For1 Lt).*

Ferrous sulphate	$FeSO_4$	0.1 g
Sodium citrate	$Na_3C_6H_5O_7$	1 g
Mineral solution		10 mL
Sodium hydrogen carbonate	$NaHCO_3$	2.5 g
Ammonium chloride	NH_4Cl	0.25 g
Di-sodium hydrogen phosphate	Na_2HPO_4	9 g
Potassium di-hydrogen phosphate	KH_2PO_4	1.5 g
Sodium di-hydrogen phosphate	NaH_2PO_4	0.6 g
Potassium chloride	KCl	0.1 g
Ammonium acetate	$C_3H_2O_2NH_4$	6.8 g

3. Results and discussions

3.1. Biofuel cell operation

Experiments were carried out using nafion and agar salt bridge as membrane. Before starting the experiment a blank run was performed in order to check error produced by the system. In the blank run, both the chambers were filled with distilled water and setup was operated for 7 days. Potential drop of 0.02 V was shown by the voltmeter at 1000 ohm resistance. For further experiments, resistance of 1000 ohm was kept constant for comparative study. Inoculation of anaerobic chamber was done with mixed bacterial culture obtained from sewage treatment plant. From Fig. 2, it is evident that the voltage produced is less for agar salt bridge. Maximum voltage was obtained after at 44 hours of inoculation and found to be 0.145V with current density of 0.06 A/m^2. Above result is similar to the results obtained by various researches with agar salt bridge as membrane [15–17,22].

Another experiment was performed with nafion as membrane under same operating condition as it was in the case of agar salt bridge. The maximum voltage of 0.5V with a current density of 0.1 A/m^2 was obtained with nafion membrane (Fig. 3). The voltage profile obtained with nafion membrane was similar to the voltage profile obtained by agar salt bridge. The voltage obtained with nafion was found significantly higher than agar salt bridge which may be due to low resistance of nafion for hydrogen ion transport as compared to agar salt bridge. The difference in the results obtained in the present

Table 2
Mineral solution composition (For 1 Lt).

Magnesium sulphate	$MgSO_4$	3 g
Manganese sulphate	$MnSO_4$	0.5 g
Sodium chloride	NaCl	1g
Ferrous sulphate	$FeSO_4$	0.1 g
Cobalt chloride	$CoCl_2$	0.1 g
Nitrilotriacetic acid	$N(CH_2COOH)_3$	1.5 g
Calcium chloride	$CaCl_2$	0.1g
Zinc sulphate	$ZnSO_4$	0.1 g
Copper sulphate	$CuSO_4$	0.01g
Aluminium potassium sulphate	$AlK(SO_4)_2$	0.01 g
Boric acid	H_3BO_3	0.01 g
Sodium molybdate	Na_2MoO_4	0.01 g

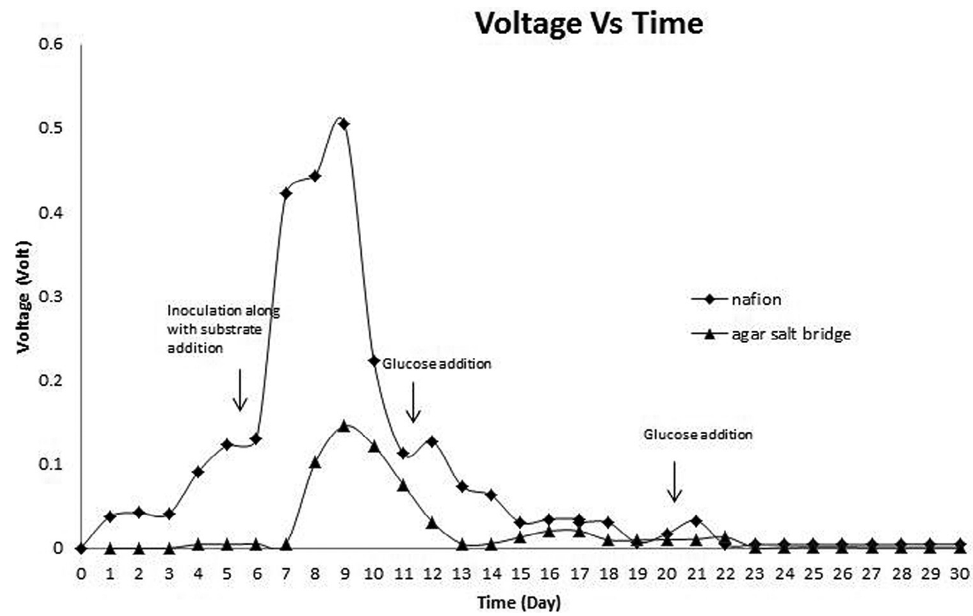

Fig. 2. Voltage production with agar salt bridge and nafion as membrane.

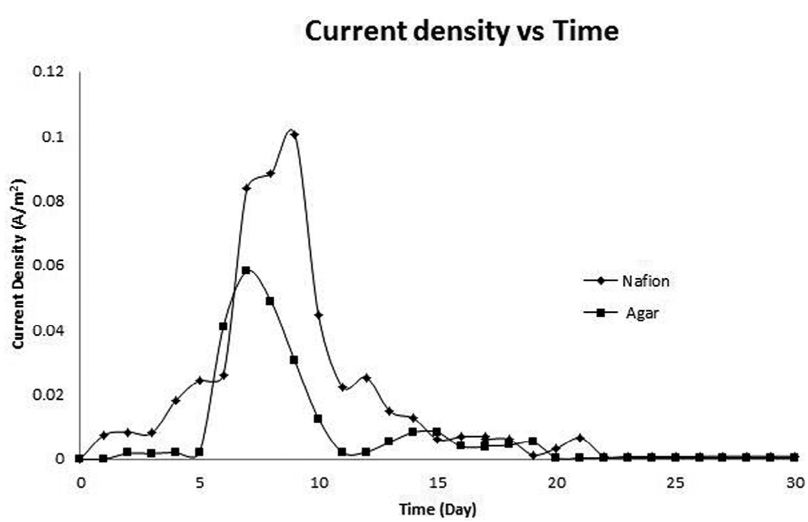

Fig. 3. Current production with agar salt bridge and nafion as membrane.

study as compared to other reported work may be due to various factors such as difference in design and operating condition of MFCs [16–18].

4. Conclusions

The study successfully demonstrated electricity production in biofuel cell using waste water obtained from local waste water treatment plant as source of substrate as well as medium with two different membranes namely nafion and agar salt and aluminum as electrode. Agar salt bridge may be a low cost alternative of proton exchange membrane but electricity production was found to be higher in case of nafion membrane than in agar salt bridge membrane in the same biofuel cell under same operating conditions which shows the low resistance of nafion as compared to agar salt bridge.

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