Enhancing Electricity Generation in MFC by Increasing Surface of Proton Transmission and Aeration

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Abstract — Microbial fuel cell is a device which converts chemical energy of a substrate directly into electricity by biological action of micro-organism in absence of air. Three chambered Microbial Fuel Cell tested under batch mode with an aeration provided to cathode chamber and little amount of HCl added to cathode chamber. Two cathode chamber dipped in single anode chamber increases the voltage and power density output at stable stage from 0.42-0.51V and 23.6-30.9mW/m2. When air was forced to cathode chamber (with small amount of HCl added in cathode chamber liquid) voltage and power density output modify from 0.51-.54V and 30.9-32.7mW/m2. At the end of experiment, the COD of waste water were measured. Enhancement in electricity generation by enlarging membrane surface and aeration were shown from the result.

Keywords: microbial fuel cell; aeration; biological action.

I. Introduction

The biological waste is produced by many industries such as milk dairy, beer factory, by-product of biological waste water treatment plant etc. India is at top position for production of milk and milk based products. The waste from such milk dairies mainly consist of proteins, polysaccharides and lipids which on hydrolysis give sugars, acids and fatty acids. According to a survey, in India, about 420 billion liters of dairy waste has been generated annually. This dairy waste can be used for the production of electricity by using Microbial Fuel Cell (MFC).

A MFC consist of mostly two chambers (cathode and anode) separated by a proton exchange membrane or agar salt bridge. Anode compartment consist of mixture of micro-organism (mostly bacteria) and waste water and cathode chamber have catholyte solution or distilled water with electrodes. An anaerobic bacteria produces electrons and protons from subtract in waste water, which run fuel cell and produces electricity[12]. The protons are transferred from anode to cathode chamber through proton exchange membrane and electrons passes through external circuit. Both electrons and protons react with oxygen on cathode surface and forms water. Oxygen is provided by aeration and acts as a reducing agent.

Anode Compartment

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

Cathode Compartment

$$24H^+ + 6O_2 + 24e^- \rightarrow 12H_2O$$

The study of previous researches suggest that by increasing the surface for proton transmission and forced aeration to cathode chamber enhances the rate of microbial reaction[1][9]. Further the liquid in cathode chamber of MFC form bio-cathodes (biological catalyst that accelerate catholic action) due to aeration if same liquid is used as that of in anode chamber. Aerobic digestion produces certain ions (like Po_4^{3-}, No_3^-, NH_4^+) which acts as a catholyte [3]. It also reduces the pollution of MFC occurring due to catholyte. Therefore it is possible to replace the catholyte solution by the same solution used in anode chamber. However maintaining acidic conditions in cathode chamber accelerate the rate of generation of electricity[14]. In this study effect of increasing the surface for proton transmission, effect of aeration to cathode compartment and effect of maintaining acidic conditions in cathode compartment on enhancing the generation of electricity is investigated.

II. Materials and Methods

A. Dairy Waste Water Sample

The dairy waste water sample was collected from local milk dairy. The sample was kept at 45°C for two days before use. This waste water was directly used for MFC test without any modification such as pH adjustment or addition of any chemical or nutrient before use. The report of analysis of waste water generated was taken from local milk dairy and summarized in Table-I.

Table I. Characteristics of Waste Water

Sr. No.	Characteristic	Unit	Value
1	pH	-	6.8
2	Colour	mg/l	Whitish
3	Total Solids	mg/l	2668
4	Suspended Solids	mg/l	509
5	COD	mg/l	1782
6	BOD at 28^0C	mg/l	636

B. MFC Construction and Operation

Two chambered typical MFC (MFC-1)

Two identical chambers of volume 750 ml were connected using proton exchange membrane. Graphite rods were used as electrode for both anode and cathode chamber. Electrodes (90 mm in length and 10 mm in diameter) were arranged in such a way to provide maximum surface area for conduction of electrons at anode and for better reaction in cathode chamber. The electrodes were connected using copper wire. The proton exchange membrane (80 mm length, 70 mm width and 0.2 mm thick) can be replace with agar salt bridge. Fig.1 shows the schematics of a two chambered MFC used for experimentation.

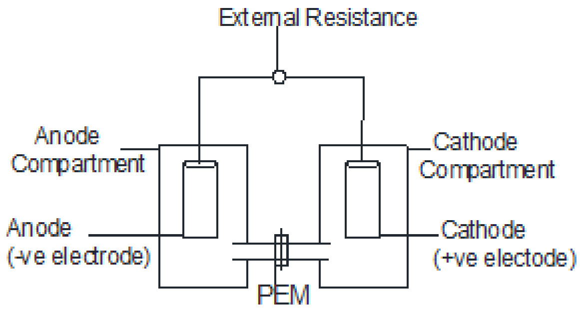

Fig. 1. Schematic diagram of typical MFC used in study

a) Three chambered MFC (MFC-2 & MFC-3)

MFC reactor was fabricated by using non-reactive plastic container of total volume approximately 3 litres and filling volume of approx. 2.75 litres. Two identical small containers (cathode chamber) of total volume 0.250 litres, containing 0.05N HCl were dipped into 3 litre chamber which contains dairy waste water and bacteria. Magnetic stirrer was used to sterilize the solution in anode compartment. Two set of experiment were performed on this structured MFC (MFC-2, MFC-3) as

MFC-2 Three chambered MFC without aeration

MFC-3 Three chambered MFC with aeration

Fig .2 shows the experimental setup of three chambered MFC and Fig. 3 provides the schematics of three chambered MFC.

Fig. 2. Experimental setup of three chambered MFC-2 & MFC-3

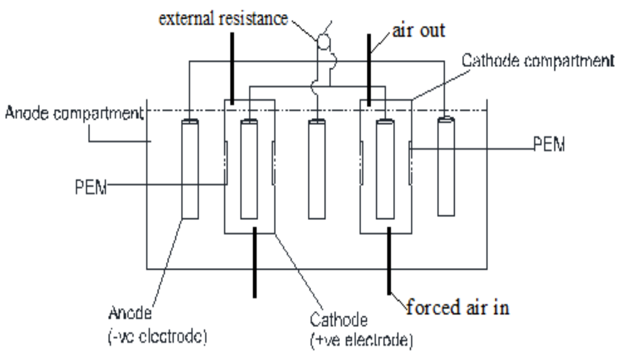

Fig. 3. *Schematic diagram of three chambered MFC*

In case of MFC-3, air was forced to cathode compartment. Whole set up was kept in air tight condition with pipes of cathode chamber kept outside. Graphite rods were used as electrode in both chambers. Copper wires were used to connect electrodes with digital multi meter.

C. Analytival Method and Calculation of Electrical Parameter

The COD of waste water was measured by using HACH COD measurement system and kit (HACH co. USA). The pH of anodic liquid is quantified with pH meter.

The voltage meter reading of MFC was taken using digital multi-meter and a data acquisition system. Current flow can be calculated as[3]

$$I = V/R_{ext} \quad (1)$$

Power density of MFC was taken as a function of voltage[3]:

$$P = V^{2/}A_{an}.R_{ext} \quad (2)$$

Where, A_{an} = area of anode,

I = current flowing in system

R_{ext} = external resistance

III. Result and Discussion

A. Effect of Increasing Area For Proton Transmission

Anode chamber consist of anaerobic bacteria. Many studies show that increase in bacteria growth rate enhances the rate of electricity production. Area of proton transmission enhances the rate of generation of electricity. Batch test were conducted to study the effect of enlarging proton exchange membrane using dairy waste water (MFC-1 and MFC-2) without supply of forced air to cathode chamber. The voltage and power density outputs are summarized in Table II.

During first stage of test (0-4 days), the voltage output of both MFC were approximately same. This was initial stage in which the bacteria were grown in new environment. After 5 days the voltage output of both MFCs was differed. The output of MFC-1 increased from 0.28V to 0.32V as compare to MFC-2 because of having more surface for proton transmission. During the stable stage (14-15 days) the voltage output of MFC-1 was 0.52V and that of MFC-2 was 0.59V. In the last stage, the decrease in voltage output for both MFCs was remarkable due to the fact that consumption rate was much more than the rate of hydrolysis of insoluble components. Voltage output was used for calculation of power densities for both the MFCs. The power density of MFC-1 was 38.56mW/m^2 and that of MFC-2 was 48.34mW/m^2 at stable state. As only difference between these two MFCs was the area of proton transmission, the above results shows enlarging PEM could enhance the electricity generation.

Table II. Comparision between Outputs of MFC-1 and MFC-2

Time (Days)	MFC-1		MFC-2	
	Voltage (V)	Power (mW/m^2)	Voltage (V)	Power (mW/m^2)
7	0.42	23.62	0.51	30.96
15	0.51	38.9	0.59	47.42
21	0.53	41.37	0.61	49.83
28	0.46	32.56	0.53	33.42

B. Effect of Aeration and Addition of HCl in Cathode Chamber

Forced air was supplied at the bottom of cathode chamber. In addition a little amount of HCl was added to liquid(distilled water) in cathode chamber (0.8 ml of HCl for 500ml of distilled water). The process of production of electricity was similar for both MFC-1 and MFC-2. In this case three chambered structure with aeration was preferred for performing experiment. The experimental results are summarized in Table II and III. The generation of electricity was highest in MFC-3 while that of MFC-1 was lowest at stable state.

The voltage outputs of MFC-3, MFC-2, MFC-1 were 0.62V, 0.59V and 0.52V respectively at stable stage. During last stage voltage output of MFC-3, MFC-2, MFC-1 decreased to 0.56V, 0.53V, 0.46V.

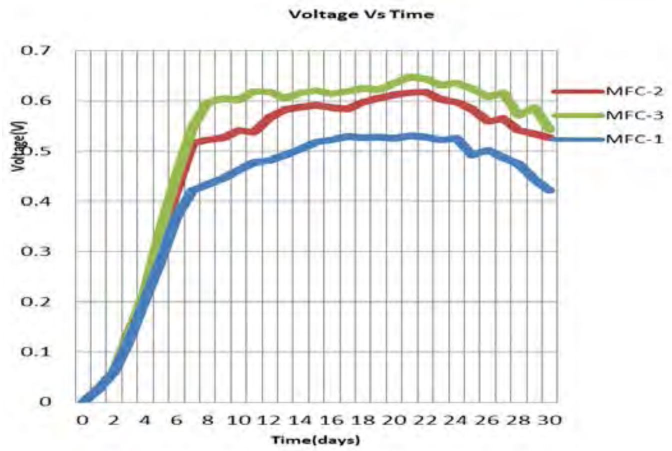

Fig. 4. Voltage output of MFC-1, MFC-2& MFC-3 during the test

Table III. Comparision between Outputs of MFC-2 and MFC-3

Time (Days)	MFC-1		MFC-2	
	Voltage (V)	Power (mW/m^2)	Voltage (V)	Power (mW/m^2)
7	0.51	30.96	0.54	32.74
15	0.59	47.42	0.62	48.28
21	0.61	49.83	0.64	51.28
28	0.53	33.42	0.56	38.26

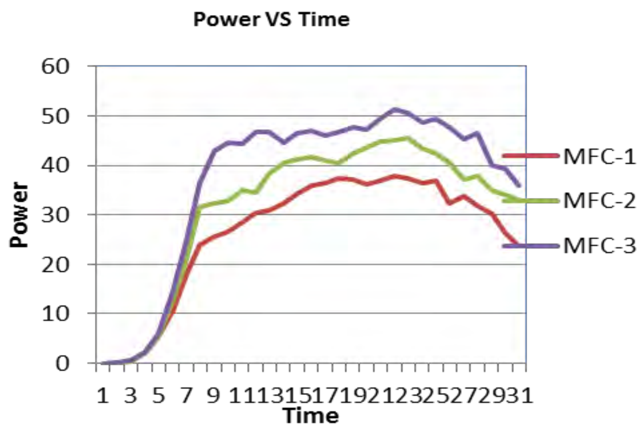

Fig. 5. Power output of MFC-1,MFC-2& MFC-3 during the test

Conclusion

The enlargement of PEM surface and forced air supply to cathode chamber with maintaining acidic condition in cathode compartment enhances the electricity production.

The voltage output of MFC increased from 0.520V to 0.592V and power density varies from 38.56mW/m^2 to 48.34mW/m^2

by enlarging PEM surface. The COD of treated water (anode chamber liquid after experiment) for two chambered and three chambered MFC without aeration was 62.38% and 53.46% of initial.

The supply of forced air to cathode compartment and of maintaining acidic condition in it also increases voltage and power density from 0.592V to 0.622V and 40.60mW/m^2 to 46.12mW/m^2 respectively. The treated water in MFC-3 showed its TCOD 46.88% of initially present which is much leaser than that of two chambered typical MFC.

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