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Impact of surface area of anode and cathode in production of green energy by using waste through Microbial Fuel Cell

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ABSTRACT
Green energy production involves the production of electricity by anaerobic digestion of organic waste. Microbial fuel cell is a device which is based on the concept of Leclanche cell (electrochemistry) and microbiology. In MFC waste products are used as substrate with cathode and anode of varying size. Microorganisms actively degrade the substrate, and bioelectricities are generated which can fulfill the low voltage power requirement in biosensors and other small devices. Domestic wastewater can be used for continuous electricity production in MFC as a substrate. Microbial fuel cell with different anode and cathode electrode sizes and the surface area of cathode and anode have been reported as important factors which influence the performance of MFC. It was found that the large surface area of anode and cathode found more effective than the smaller one. This study shows that by using carbon anode and cathode having an area of 74.18cm² produce 995mv electricity while anode and cathode with area of 9.98 cm² generate 75.76 mv only in same condition.
Key words: *Green energy, Microbial fuel cell (MFC) , cathode, anode, surface area , biosensors*

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INTRODUCTION

An inevitable consequence of development and industrial progress is generation of waste. Currently global MSW generation levels are approximately 1.3 billion tonnes per year, and are expected to increase to approximately 2.2 billion tonnes per year by 2025. This represents a significant increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years. MSW generation rates are influenced by economic development, the degree of industrialization, public habits, and local climate. Generally, the higher the economic development and rate of urbanization, the greater the amount of solid waste produced. About 0.1 million tonnes of municipal solid waste is generated in India every day. That is approximately 36.5 million tonnes annually. Per capita waste generation in major Indian cities ranges from 0.2 Kg to 0.6 Kg. The urban local bodies spend approximately Rs.500 to Rs.1500 per tonne on solid waste for collection, transportation, treatment and disposal. About 60-70% of this amount is spent on collection, 20-30% on transportation and less than 5% on final disposal. Waste collection efficiency in Indian cities ranges from 50% to 90%. Out of the total municipal waste collected, on an average 94% is dumped on land and 5% is composted [1]. Now a days, microbial fuel cell (MFCs) are captivating the attention due to their mild operating conditions and using variety of biodegradable substrates as fuel. The traditional MFC is consisted of anode and cathode compartments both chambers are separated by using semi permeable membrane but there are single chambered. According to their tolerance level of temperature bacterial reactions carried out, ranging from moderate (15-35 °C) to high and low (<15 °C). These biodegradable reactions inside the microbial fuel cell degrade the substances having volatile acids, proteins, carbohydrates, alcohols and even cellulose also. The microorganisms inoculated inside the cell chamber and they oxidize fuel and generate CO_2, electrons and protons. With the help of external electric circuit, protons are transferred to the cathodic chamber through the membrane. In the cathodic chamber in aerobic atmosphere electrons and protons are consumed and combine with oxygen to form water. In aerobic condition microorganism consumes sugar and produce carbon dioxide

and water but in anaerobic condition they produce carbon dioxide protons and electrons as describe below.

$C_{12}H_{22}O_{11} + 13H_2O \rightarrow 12CO_2 + 48H^+ + 48e^-$

Microorganisms used for degrading the substrate inside the chamber, actively catabolize substrate, and bioelectricities are generated. MFCs could be utilized as power generator in small devices such as biosensor [6]. There are some barriers in the purview of MFS like such as low power and current density. MFC is also used to treat the domestic waste water where, domestic wastewater can be used for continuous electricity production [4]. Fruit and vegetable wastes were employed as a substrate for microbes isolated from high Andean region in a single-chambered MFC. Different bio waste as substrate oxidizing agent, material used as an electrode its size and surface area are played important role in electricity generation as well as also affect the power generation capacity of MFCs [7].

Power generation in microbial fuel cell (MFC) at different cathode electrode surface area was examined in two-chambered system with sodium acetate as carbon sources. When the anode surface area of 66 cm^2 was used, the maximum power density increased by 44% when the cathode surface areas were increased from 66 cm^2 to 336 cm^2 and decreased by 21% when the cathode surface area was reduced to 14 cm^2.[3]

MATERIAL AND METHODS

Experimental Section

The bio waste, used for generating the electricity was kitchen waste (KW) included waste grains, rotten fruit pulp, peel of vegetables and fruit etc, cow dung (CD), poultry waste (PW) and soil. Kitchen waste was collected from canteen of Gandhi Bhawan girl's hostel of GBPUA&T. Cow dung and poultry waste were collected from Instructional Dairy and poultry farm Nagala situated in University campus. The collection of municipal solid waste was done at nearby area of MSW disposal sites. In setup 1two plastic jar of same size and capacity of 2litre are used as cathodic and anodic chamber separately. A hole of same size at the same place on both the jar was made for inserting the salt bridge, which connected both the jars. In the cathodic and anodic jar a small hole was made on the cover of the jars for fitting the carbon electrode (L= 5cm, Dia= 0.6 cm) with surface area of 9.98 cm2 .Another one more setup 2 are structured in which combination of kitchen waste with cow dung and poultry waste used as substrate but this time the dimension of anode and cathode has changed (L=15cm,Dia= 1.5 cm) with surface area of 74.18 cm^2. The details of different experimental set ups and their graphics are given in Table1 and photograph 1.

Table 1. Setup arranged in experimental procedure

Setup-1	KW+PW+CD	Carbon	Length= 5 cm Dia= 0.6 cm Area = 9.98 cm^2	Potassium ferricyanide
Setup-2	KW+PW+ CD	Carbon	Length=1 5 cm Dia= 1.5 cm Area = 74.18cm^2	Potassium ferricyanide

1 [a]

1 [b] **1[c]**

Photograph 1. [a] Design of MFC with electrode of different dimension, [b] carbon rod (length=15cm, dia =1.5 cm), [c] Carbon rod(length = 5cm , dia= 0.6 cm

SETUP-1

The experiment carried out by taking mixture of kitchen waste with cow dung and poultry waste as a substrate as a feed in microbial fuel cell for harnessing electron through microbial degradation of mixture of waste with the help of potassium ferricyanide (50 g/L) as an oxidizing agent and putting carbon electrode of dimension length =5cm and dia= 0.6 cm in both the chambers of cathode and anode of MFC. The result obtained from this experimental setup reveals that the maximum voltage generation of 757.6 mV takes place on 2th day from the starting of experiment and minimum was 208 mV on 7th day of the experiment Generation of voltage through Microbial fuel cell shown in Table 2. This result indicates that generation of electricity from mixture of waste , increases rapidly and after 2 days it start decreasing due to maximum utilization of organic material present in kitchen waste. The similar trend of voltage production from the mixture of waste (cow dung, slurry, rice washing water and vermin compost) has been reported [2].

Table2 : Generation of voltage through Microbial fuel cell Setup-1 by using Kitchen waste (KW), cow dung (CD) and poultry waste (PW) in mV where carbon rod as electrode (l= 5 cm, dia=0.6 cm) and Potassium ferricyanide used as an oxidizing agent

S.No.	Surface area of electrode	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
1	KW+ CD+ PW	720	758	385	344	268	250	209
		725	760	387	346	264	245	210
		715	755	382	342	265	242	205
	Average	720	757.6	384.66	344	265.66	245.66	208
	S.E	±2.88	±1.45	±1.45	±1.15	±1.20	±2.33	±1.52

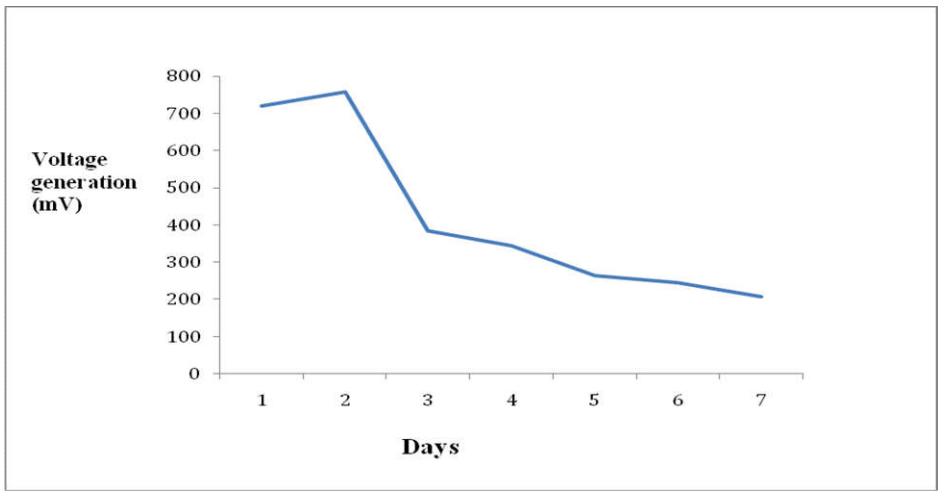

Figure 1**:** Graphical representation of generation of average voltage through Microbial fuel cell by Setup-1 using Kitchen waste, cow dung and poultry waste

The changes occurred in Setup 1 of MFC during 7 days of experimental setup has shown in graphical form in Figure no. 1.

SETUP-2

The experiment carried out by taking mixture of kitchen waste with cow dung and poultry waste as a substrate as a feed in microbial fuel cell for harnessing electron through microbial degradation of mixture of waste with the help of potassium ferricyanide (50 g/L) as an oxidizing agent Here dimension of electrode has been changed . Carbon electrode of dimension length =15cm and dia= 1.5 cm was used in both the chambers of cathode and anode of MFC. The result obtained from this experimental setup reveals that the maximum voltage generation of 990 mV takes place on 7th day from the starting of experiment and minimum was 206.6 mV on 11th day of the experiment. The details of result obtained from this experimental setup are given in Table 3. This result indicates that generation of electricity from mixture of waste and with increase of surface area of electrode ,increases up to 7th day and after that it start decreasing due to maximum utilization of organic material present in substrate. The similar trend of voltage production has been reported by Owada *et al.*, [5] .They changed **s**urface areas of cathode and anode from 6 to 25 cm^2 and it was observed that the electrical power outputs were proportional to the cathode.

Table 3. Voltage generation in mV through MFC Setup-2 by using Potassium ferricyanide (oxidizing agent) with substrate (KW+CD+PW) and Carbon rod as electrode (L=15 cm, dia=1.5 cm)

S.N0.	Surface area of electrode	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11
1	74.18cm^2	830	900	950	955	960	975	990	509	232	218	215
		835	905	955	957	965	976	995	510	235	215	210
		820	915	945	954	971	972	985	505	230	219	205
	Average	828.3	906.6	950	955.3	965.3	974.3	990	508	232.3	217.3	206.6
	S.E	±4.44	±4.40	±2.88	±0.88	±3.17	±1.20	±2.88	±1.52	±1.45	±1.20	±4.40

The graphical representation of electricity produced through MFC in Setup 2 in 11 days of experimental setup has shown in Figure 2.

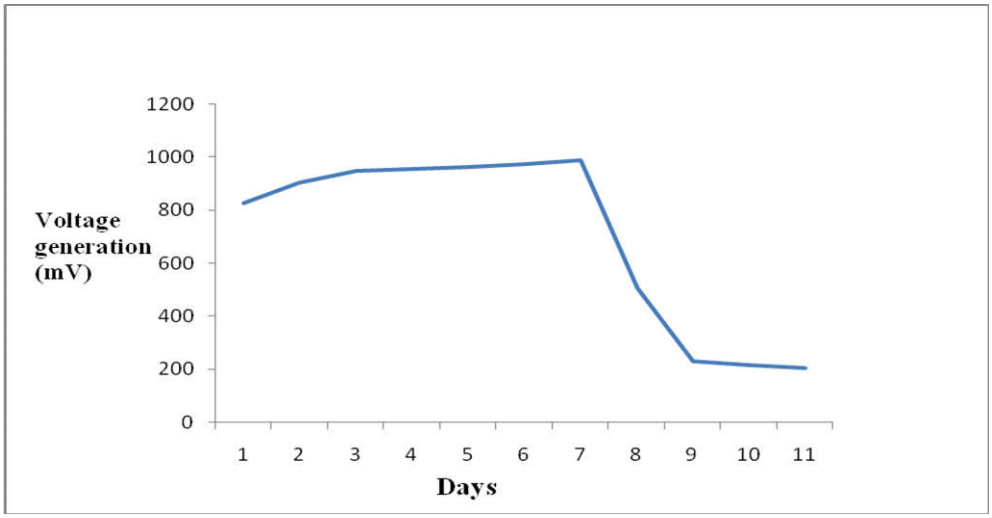

Figure 2. Graphical representation of average voltage generation in mV through MFC Setup-5 by using Potassium ferricyanide (oxidizing agent) with substrate (KW+CD+PW) and carbon rod as electrode (L=15 cm, dia=1.5 cm)

The comparison of result obtained from different setup1 and setup 2 has shown in Table 4 and its graphical representation has presented in Figure 3.

Table 4: Generation of voltage in mV through MFC by using Carbon electrode of different surface area in uniform condition having KW+CD+PW as a substrate and Potassium ferricyanide as an oxidizing agent

S.No.	Surface area of electrode	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day 8
1	9.98cm²	720	758	385	344	268	250	209	200
		725	760	387	346	264	245	210	205
		715	755	382	342	265	242	205	201
	Average	720	757.66	384.66	344	265.66	245.66	208	202
	S.E	±2.88	±1.45	±1.45	±1.15	±1.20	±2.33	±1.52	±1.52
2	74.18cm²	830	900	950	955	960	975	990	509
		835	905	955	957	965	976	995	510
		820	915	945	952	954	971	985	505
	Average	828.33	906.66	950	954.66	959.66	974	990	508
	S.D	±4.40	±4.40	±2.88	±1.45	±3.17	±1.52	±2.88	±1.52

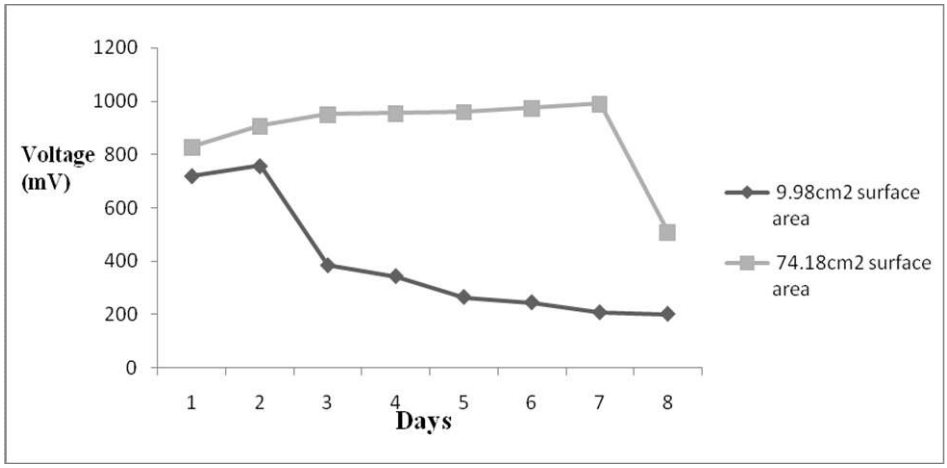

Figure 3 : Graphical representation of voltage production in mV through MFC by using Carbon electrode of different surface area in uniform condition having KW+CD+PW as a substrate and Potassium ferricyanide as an oxidizing agent

RESULTS

The observation and results obtained during the study envisaged that anode and cathode with surface area of 9.98 cm² (dimension L= 5 cm dia=0.6 cm) produces 757.66 mv electricity while under same condition the anode and cathode having surface area of 74.18 cm² (dimension L= 15 cm, dia = 1.5 cm) generated 990mv electricity during same time span of 7 days .

DISCUSSION

This variation is shown in electricity production under uniform lab condition of setup because large surface area of cathode and anode provide better chance and effective purview to the microorganism to grow fast and also increase area of contact with the substrate.

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