

Electricity Generation from Microbial Fuel Cell by using Different Bio-Wastes as Substrate

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Received 2 January 2017; Accepted 3 February 2017; Published online 22 February 2017

Abstract Increased anthropogenic activities and consumption of natural resources have led to the decline in fossil fuel. To resolve an increasing global demand in energy, a source of sustainable and environmentally friendly energy is needed. Recently, great attentions have been paid to microbial fuel cells (MFCs) due to their mild operating conditions and using variety of biodegradable substrates as fuel. This paper describes the suitability of the Microbial fuel cell (MFC) for generation of electrical power through bio-waste. In this study, blends of bio-waste were tested in double-chamber microbial fuel cells (DMFC)

devices to generate bioelectricity. Biodegradable wastes are a good source of energy. Kitchen Waste, cow dung, poultry waste and municipal solid waste was used as a feeding material inside the microbial fuel cell with potassium ferricyanide as an oxidizing agent and carbon rod (1=5 cm, d=0.6 cm) as an electrode. These waste provided energy to micro organism. Combination of kitchen waste with cow dung and poultry waste was found more capable to produce maximum voltage of 757.6 mV in 7 days of experiment while when kitchen waste used separately and in combination with cow dung, poultry waste and MSW in MFC as a feeding material maximum 405 mV and 559 MV voltage was obtained respectively.

Keywords Microbial fuel cell, Solid bio-waste, Electricity.

Introduction

Asia generates 4.4 billion tones of solid waste annually out of which 790 million tonnes is municipal solid waste and 950 million tones of other solid waste [1]. In the near future, the trends for new and alternative renewable energies are gradually increasing [2—4]. Among renewable alternatives, microbial fuel cell (MFC) has created great interests for many researchers due to its possibility of directly harvesting electricity from organic wastes and renewable biomass [5]. The microbial fuel cell (MFC) technology has been widely developed pursuing both outcomes: generation of electricity and treatment of wastes from differ-

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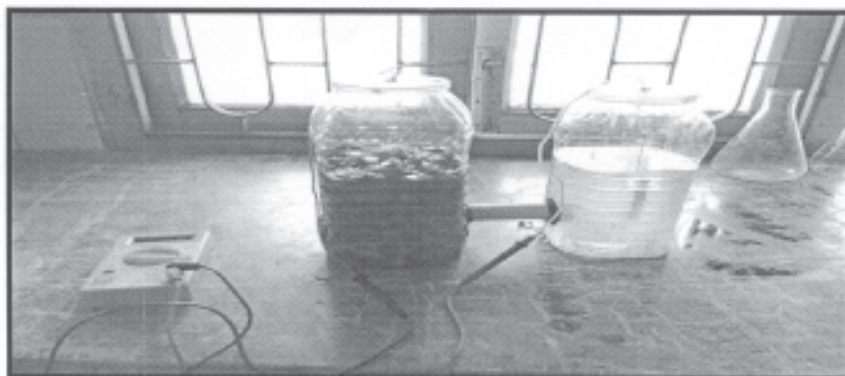


Fig. 1. Design of MFC.

ent derivations (organic or inorganic). Microbial fuel cells are not new – the concept of using microorganisms as catalysts in fuel cells was explored from the 1970s. A microbial fuel cell (MFC) is a device that uses bacteria to catalyze the conversion of organic matter into electricity [6–9]. Although electrical current produced by bacteria was observed by Potter in 1911. However, in the early 1990s, FCs became for more appealing devices; consequently, MFCs were considered as promising technology. India is an agricultural based country and holds second position in production of food and vegetables in the world and contributes 10% in fruits and 14% in vegetables in the world production [10]. It is reported that 650 MT waste is generated from agriculture, which include

sugarcane, baggase, paddy and wheat strew. Food waste is loss of food occurring during the retailing and final consumption stages due to the behavior of consumers and retailers that is, the throwing away of food [11].

Micro organism present in solid waste such as fungi, bacteria, Protozoa, may be further used for degradation of food waste. Idea of obtaining energy from bacteria began in 1911 later on concept of using microorganisms as catalysts in fuel cells was explored from the 1970s and microbial fuel cells was also used for treating domestic waste water [12]. MFC bacteria directly transfer electrons to the anode, bacteria have electrochemically active redox proteins such as cytochromes on their outer membrane which help in transferring of electrons into anode [13]. On the basis of source MSW is classified into three types: Residential or household waste, commercial waste and municipal waste and municipal wastes arise from area sources like parks, streets. Food wastes, paper, cardboard, plastics, glass, textiles, wood, street sweeping, landscape and tree trimmings, general wastes from parks, beaches and other recreational areas come under MSW [14]. Open burning of municipal solid waste releases pollutants into the atmosphere and also pollute the ground water resources. It includes carbon mono oxide (CO), hydrocarbons (HC), nitrogen dioxides (NO_x) and sulfur dioxide (SO₂) and particulate matter (PM). India is an agricultural based country

Table 1. The details of different experimental set ups are given as below.

Sl. No.	Use of biowaste material	Type of emelectrode	Dimension of electrode	Oxidizing agent
Setup-1	KW	Carbon	Length=5 cm Dia=0.6 cm	Potassium ferricyanide
Setup-2	KW+PW +CD	Carbon	Length=5 cm Dia=0.6 cm	Potassium ferricyanide
Setup-3	KW+PW +CD+MSW	Carbon	Length=5 cm Dia=0.6 cm	Potassium ferricyanide

Table 2. Generation of voltage through microbial fuel cell Setup-2 by using kitchen waste in mV where carbon rod as electrode (L=5 cm, dia=0.6 cm) and potassium ferricyanide used as an oxidizing agent.

Sl. No.	Substrate	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
1	Kitchen waste	400	405	385	140	99	52	34
		401	408	382	139	101	50	36
		389	402	380	141	98	51	30
	Average	396.66	405	382.33	140	99.33	51	33.33
	SE	±3.84	±1.73	±1.45	±0.57	±0.88	±0.57	±1.76

and holds second position in production of food and vegetables in the world and contributes 10% in fruits and 14% in vegetables in the world production. Cowdung enhance the electricity generation capacity of microbial fuel cell. Cowdung has variety of electrogenic bacteria. High concentrated slurry of livestock solid waste provides electrochemically active bacteria to the cell and increases the stable energy production [15]. The major limiting factors that hinder the practical implementation of MFCs at large scale, are the cost of materials used and the difficulties in the scale-up process [16].

(Sincere appreciation is extended to Govind Ballabh Pant University of Agriculture and Technology, Pantnagar to carry out this work. The author gratefully acknowledges Faculty of Environmental Sciences for providing facilities to this study).

Materials and Methods

The biowaste, used for generating the electricity was kitchen waste included waste grains, rotten fruit pulp, peel of vegetables and fruit, cowdung, poultry waste and soil. Kitchen waste was collected from canteen of Gandhi Bhawan girls hostel of GBPUA and 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 two plastic jar of same size and capacity of 2 l were used as cathodic and anodic chamber separately (Fig. 1 and Table 1). 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=5 cm, Dia=0.6 cm). In setup 1, anodic chamber having carbon rod as an electrode filled with kitchen waste separately as substrate and salt water (to make the substrate more conductive) and holes on the jar were air tight by fixing m-seal to provide anaerobic condition, while the cathodic chamber was filled with potassium ferricyanide oxidizing agent solution (50 g/L). Upper side of the electrodes was connected with Cu wire and it was attached to multimeter to record the milivolt voltage generated from the electrodes (cell).

For making the salt bridge between anodic and cathodic chamber 8 g agar and 15 g NaCl was allowed

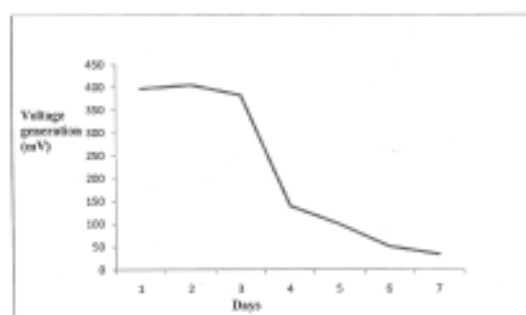


Fig. 2. Graphical representation of generation of average voltage through microbial fuel cell Setup-2 by using kitchen waste in mV where carbon rod as electrode (L=5 cm, dia=0.6 cm) and potassium ferricyanide used as an oxidizing agent.

Table 3. Generation of voltage through microbial fuel cell Setup-3 by using kitchen waste, cow dung and poultry waste in mV where carbon rod as electrode (l=5 cm, dia=0.6 cm) and potassium ferricyanide used as an oxidizing agent.

Sl. No.	Substrate	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
	SE	±2.88	±1.45	±1.45	±1.15	±1.20	±2.33	±1.52

to boil inside an oven for 20 min at 100°C temperature. Hot solution after heating was poured into sawed PVC pipe having length of 4 inches sealing one end by polythene and cool for 24 h in a refrigerator [13]. This salt bridge act as exchange membrane for transferring the proton from anodic chamber to cathodic chamber. For preparing the solution for salt bridge usually NaCl with agar is used because NaCl is chemically inert so it does not react with any of the chemicals used in the cells.

For making the salt water with conductivity of 31.3 mS/cm, 250 million molar salt solutions were required. By dissolving the 14.61 g of NaCl in 1 l of distilled water we achieved salt solution of 250 mM. It has been reported Wang et al. [17] that at conductivity of 31.3 mS/cm performance of electrode was found optimum. Another two more setups (setup 2, setup 3) were constructed in which combination of kitchen waste with cow dung and poultry waste (setup 2) and in setup 3 combination of kitchen waste with cow dung, poultry waste and municipal solid waste were used as substrate under the similar condition as created in setup 1.

Results and Discussion

Setup-1

The experiment carried out by taking kitchen waste as a substrate as a feed in microbial fuel cell for harnessing electron through microbial degradation of

kitchen waste with the help of potassium ferricyanide (50 g/L) as an oxidizing agent and putting carbon electrode of dimension length=5 cm 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 405 mV takes place on 2th day from the starting of experiment and minimum was 33.33 mV on 7th day of the experiment. The details of result obtained from this experimental setup are given in Table 2 and same is also shown in Fig. 2. This obtain result indicates that generation of electricity from kitchen waste, increases rapidly and after 2 days it start decreasing due to maximum utilization of organic material present in

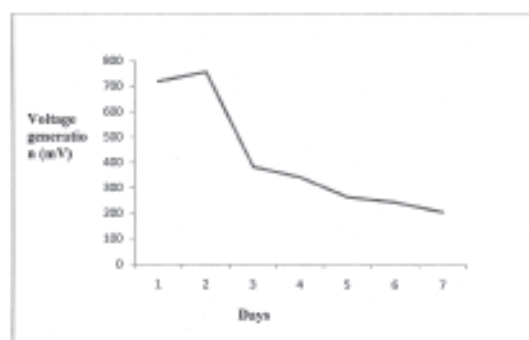


Fig. 3. Graphical representation of generation of average voltage through microbial fuel cell Setup-3 using kitchen waste, cow dung and poultry waste in mV where carbon rod as electrode (l=5 cm, dia=0.6 cm) and potassium ferricyanide used as an oxidizing agent.

Table 4. Generation of voltage through microbial fuel cell Setup-3 by using kitchen waste, cow dung poultry waste and municipal solid waste in mV where carbon rod as electrode (1=5 cm, dia=0.6 cm) and potassium ferricyanide used as an oxidizing agent.

Sl. No.	Substrate	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
		258	560	247	190	95	90	88
	KW+CD+PW+MW	260	562	250	195	96	92	90
		255	555	245	185	92	89	85
	Average	257.66	559	247.33	190	94.33	90.33	87.66
	SE	±1.45	±2.08	±1.45	±2.88	±1.201	±0.88	±1.45

kitchen waste. The similar trend of voltage production from the kitchen waste has been reported by Moqsud and Omine [18] by using 120 gm kitchen waste, 120 gm leaf mold and 120 gm micro organism.

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 and putting carbon electrode of dimension length=5 cm 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. The details of result obtained from this experimental setup are given in Table 3 and same is also shown in Fig. 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, shurry, rice washing water and vermicompost) has been reported by Barua and Deka [13].

Setup-3

The experiment carried out by taking mixture of

kitchen waste with cow dung, poultry waste and municipal solid 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=5 cm 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 559 mV taken place on 2th day from the starting of experiment and minimum was 87.66 mV on 7th day of the experiment. The details of result obtained from this experimental setup are given in Table 4 and same is also shown in Fig 4. This result indicates that generation of electricity from mixture of

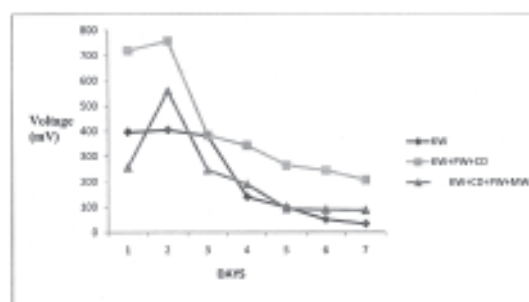


Fig. 4 . Graphical representation of generation of voltage through microbial fuel cell by using different substrate in mV where carbon rod as electrode (1=5 cm, dia=0.6 cm) and potassium ferricyanide used as an oxidizing agent.

waste, increases rapidly and after 2 days it start decreasing due to maximum utilization of organic material present in bio-waste. The similar trend of voltage production from the mixture of waste (cow dung, slurry, rice washing water and vermicompost) has been reported by Barua and Deka [13].

The comparison of different solid waste substrate as feed material in microbial fuel cell were carried out by taking cow dung, poultry waste, kitchen waste separately and its combination with cowdung, poultry waste and municipal waste separately and in combination in similar condition of the experimental setup for voltage generation from feed. In the experiment potassium ferricyanide was taken as oxidising agent, carbon rod as electrode having size of length 5 cm and dia 0.6 cm and salt bridge prepared by agar and NaCl for optimization of result, in similar experimental condition. The result obtained from this experiment are given in Table 5. This table reveals that when kitchen waste used separately as a substrate in microbial fuel cell, it generated the maximum voltage of 405 mV on 2nd day and minimum of 33.3 mV on 7th day. However when kitchen waste mixed with cow dung and poultry waste with same oxidizing agent, the maximum voltage generation was 757.66 mV obtained on 2nd day after that the voltage declined and minimum voltage came down to 208 mV on 7th day. It was observed that using municipal solid waste with the kitchen waste, cow dung and poultry waste as a substrate decreases the performance of microbial fuel cell the maximum reading of voltage obtained was 559 mV on 2nd day and minimum was 87.66 mV on 7th day as shown in Fig 5. Mixture of solid biowaste cow dung, slurry, rice water washing and vermicompost can actually result in higher extractable voltage than any single component. Cow dung provides more favorable condition for microbes generation as it contains high concentration of micro nutrients those are essential for growth of bacteria.

Conclusion

The observation and results obtained during the study envisaged that kitchen waste included waste grains, rotten fruit pulp, peel of vegetable and fruit

used as substrate separately with cow dung, poultry waste and municipal solid waste in uniform condition and maximum output of 757.6 mV was obtained when kitchen waste used with cow dung and poultry waste in comparison to 405 mV and 559 mV were obtained when kitchen waste used separately and when it mixed with cow dung, poultry waste and municipal solid waste respectively.

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