

Comparative Study of Different Biomass on Bio-electricity Generation Using Microbial Fuel Cell

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Abstract

Pakistan facing problem with respect to energy having abounded source of fossil fuel. On the basis of that one of new technology which getting importance nowadays is nothing but MFC. In this regard work were carried out on different biomass as substrate in Microbial Fuel Cell for electricity generation. Among the different biomass sewage sludge had potential for generation of 2500mv/l. When compare it other sources the yield is 270mv/l for carbo manure, 229mv/l for waste water, 330mv/l for cow manure. Sewage sludge containing organic compound higher percentage of glucose, due to this will give the good results for power generation and environment.

Key words: Sewage sludge; Organic compound; Biomass; Electricity generation; Microbial fuel cell

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INTRODUCTION

The construction and analysis of MFCs requires knowledge of different scientific and engineering fields, ranging from microbiology and electrochemistry to materials and environmental engineering. Describing MFC systems therefore involves an understanding of these different scientific and engineering principles (Logan and Hamelers et al., 2006). Microbial fuel cells (MFCs) are typically designed as a two-chamber system with the bacteria in the anode chamber separated from the cathode chamber by a polymeric proton exchange membrane (PEM). Most MFCs use aqueous cathodes where water is bubbled with air to provide dissolved oxygen to electrode. To increase energy output and reduce the cost of MFCs, we examined power generation in an air-cathode MFC containing carbon electrodes in the presence and absence of a polymeric proton exchange membrane (PEM). Bacteria present in domestic wastewater were used as the biocatalyst, and glucose and wastewater were tested as substrates (Liu and Logan, 2004). Microbial fuel cells (MFCs) have been used to produce electricity from different compounds, including acetate, lactate, and glucose. We demonstrate here that it is also possible to produce electricity in a MFC from domestic wastewater, while at the same time accomplishing biological wastewater treatment (removal of chemical oxygen demand; COD). Tests were conducted using a single chamber microbial fuel cell (SCMFC)

containing eight graphite electrodes (anodes) and a single air cathode. The system was operated under continuous flow conditions with primary clarifier effluent obtained from a local wastewater treatment plant. The prototype SCMFC reactor generated electrical power (maximum of 26 mW m⁻²) while removing up to 80% of the COD of the wastewater. Power output was proportional to the hydraulic retention time over a range of 3–33 h and to the influent wastewater strength over a range of 50–220 mg/L of COD.

Current generation was controlled primarily by the efficiency of the cathode. Optimal cathode performance was obtained by allowing passive air flow rather than forced air flow (4.5–5.5 L/min) (Liu and Ramnarayanan et al., 2004). There has been an increase in recent years in the number of reports of microorganisms that can generate electrical current in microbial fuel cells. Although many new strains have been identified, few strains individually produce power densities as high as strains from mixed communities. Enriched anodic biofilms have generated power densities as high as 6.9 W per m² (projected anode area), and therefore are approaching theoretical limits. To understand bacterial versatility in mechanisms used for current generation, this Progress article explores the underlying reasons for exocellular electron transfer, including cellular respiration and possible cell–cell

communication (Logan, 2009). Maximum power densities by air-driven microbial fuel cells (MFCs) are considerably influenced by cathode performance. We show here that application of successive polytetrafluoroethylene (PTFE) layers (DLs), on a carbon/PTFE base layer, to the air-side of the cathode in a single chamber MFC significantly improved columbic efficiencies (CEs), maximum power densities, and reduced water loss (through the cathode). Electrochemical tests using carbon cloth electrodes coated with different numbers of DLs indicated an optimum increase in the cathode potential of 117 mV with four-DLs, compared to a <10 mV increase due to the carbon base layer alone. In MFC tests, four-DLs was also found to be the optimum number of coatings, resulting in a 171% increase in the CE (from 19.1% to 32%), a 42% increase in the maximum power density (from 538 to 766 mW m⁻²), and measurable water loss was prevented (Logan, 2009). Direct electron transfer from different *Shewanella putrefaciens* strains to an electrode was examined using cyclic voltammetry and a fuel cell type electrochemical cell. Both methods determine the electrochemical activity of the bacterium without any electrochemical mediators. In the cyclic voltammetric studies, anaerobically grown cells of *Shewanella putrefaciens* MR-1, IR-1, and SR-21 showed electrochemical activities, but no activities were observed in aerobically grown *Shewanella putrefaciens* cells nor in aerobically and anaerobically grown *E. coli* cell suspensions. The electrochemical activities measured by the cyclic voltammetric method were closely related to the electric potential and current generation capacities in the microbial fuel cell system. Cytochromes localized to the outer membrane are believed to facilitate the direct electron transfer to the electrode from the intact bacterial cells (Kim and Park et al., 2002). A mediator-less microbial fuel cell was optimized in terms of various operating conditions. Current generation was dependent on several factors such as pH, resistance, electrolyte used, and dissolved oxygen concentration in the cathode compartment. The highest current was generated at pH 7. Under the operating conditions, the resistance was the rate-determining factor at over 500 Ω . With resistance lower than 500 Ω , proton transfer and dissolved oxygen (DO) supply limited the cathode reaction. A high strength buffer reduced the proton limitation to some extent. The DO concentration was around 6 mg l⁻¹ at the DO limited condition (Gil, Chang et al. 2003). A microbial fuel cell containing a mixed bacterial culture utilizing

glucose as carbon source was enriched to investigate power output in relation to glucose dosage. Electron recovery in terms of electricity up to 89% occurred for glucose feeding rates in the range 0.5–3 g l⁻¹ d⁻¹, at powers up to 3.6 W m⁻² of electrode surface, a fivefold higher power output than reported thus far (Rabaey and Lissens et al., 2003). Microbial production of electricity may become an important form of bioenergy in future because MFCs offer the possibility of extracting electric current from a wide range of soluble or dissolved complex organic wastes and renewable biomass. A large number of substrates have been explored as feed. The major substrates that have been tried include various kinds of artificial and real wastewaters and lignocellulosic biomass. Though the current and power yields are relatively low at present, it is expected that with improvements in technology and knowledge about these unique systems, the amount of electric current (and electric power) which can be extracted from these systems will increase tremendously providing a sustainable way of directly converting lignocellulosic biomass or wastewaters to useful energy (Pant and Van Bogaert et al., 2010). *Saccharomyces cerevisiae* sp. as a mediator and potassium ferricyanide as an oxidizing agent were used for the conversion of sewage organics into electric current and power generation using lab-scale double chamber MFC. The cells were connected in series with the anodic and cathodic solutions being introduced in batch and continuous modes. A maximum voltage of 830mV (3.3 mA) was obtained per liter of the sludge with the anode in batch- feed and cathode in continuous modes of operation under optimum conditions of the operating parameters of oxygen flow rate, pH and substrate concentration (Aziz and Memon et al., 2013). The main purpose of this research work to generate electricity from sewage sludge and other biomass that are waste water, cow manure, carbo manure comparatively.

MATERIALS AND METHODS

Research work was conducted at fuels and biochemical engineering lab at chemical engineering department Mehran University of engineering and technology.

Sp: *saccharomyces cerevisiae* was taken as biocatalyst for conversion of organic matter into bio-electricity in MFC for power generation and sewage sludge is taken from waste water treatment plant, amount of sewage sludge that were taken about 1lit. And other biomass also taken from

different region of Sindh province for analysis and treatment.



Figure 1: Microbial Fuel Cell

Microbial Fuel Cell construction

Microbial fuel cell that were used to carry out experimental work is two chamber. One is anodic chamber in which an aerobic condition is used, that contain substrate and biocatalyst. Cathodic chamber containing salt water and aerobic condition is used (Liu H et al., 2004). Electrodes are used to transfer the electrons and salt bridge is used to transfer the proton. Salt bridge made from agar and common salt. Microbial fuel cell configuration is shown in figure which shows the overall process of microbial fuel cell. Two chamber is taken between them salt bridge is used to transfer proton from cathodic chamber to anodic chamber.

Table 1: Dimensions of MFC chamber

Items	Height (in)	Dia (in)	Length (in)
Cathodic chamber	15	9	-
Anodic chamber	15	9	-
Salt bridge	-	4	4

Operational Conditions

Sewage sludge that are used taken from waste water treatment plant, because we know the composition of sludge that are produced from treatment of waste water. Pure strain of *saccharomyces service* is used to carry out the process. Air is used in cathodic chamber to oxidize the proton coming from anode chamber. Salt bridge is used to transfer the proton from anode chamber to cathodic chamber and external circuit is used for transfer of electrons coming from anode chamber

Analysis

In MFC different parameter were analyzed during experimental work on it.

pH

Different pH ranges for activity of biocatalyst were utilized for getting optimized condition for electricity generation. Because pH had significant effect on microbial activity of microbes. Due to basicity and acidity the pH had significantly effect from 6-8.5pH.

Oxygen flow rate

During microbial growth aeration rate had significant effect on bio-electricity generation. From 15-60ml.min for cathode chamber regarding oxidation of proton from anode chamber.

Voltage Generated

Voltage were analyzed by multimeter coupling with different substrate concentration, pH, and aeration rate. Voltage was continuously measured after 24 hr microbial growth of microorganism by a multimeter with a data acquisition system. Current (I) was calculated from the voltage (V) by $I = V/R_e$, where R_e is the external resistance. Power (P) was calculated as $P = IV$. (Logan et al., 2006)

RESULTS AND DISCUSSION

Electricity generation from different biomass

First 24 hour there is no any generation after that current generation observed continually. After every 15 minutes results were observed and analyzed by multimeter. The maximum voltage observed at 140 minutes of operation about 2450mv/l. after 165 minutes voltage shown on multimeter decreases, due to organic load in substrate decreases. After the MFC treatment, the total organic carbon concentration in sewage sludge utilize to produce electricity. In MFC, microorganisms oxidize organic matter in the anode chamber (anaerobic conditions) producing electrons and protons. Electrons transfer via the external circuit to the cathode chamber where electrons, protons and electron acceptor (mainly oxygen) combine to produce water.

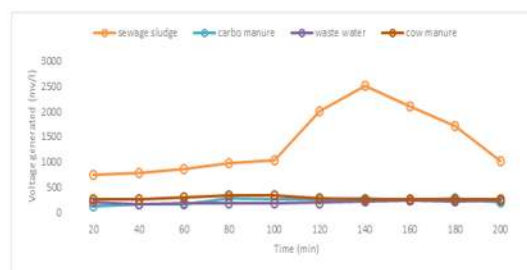


Figure 2: Voltage vs Time

Effect of oxygen flow rate on voltage generation

Different flow rate of oxygen were studied to know about the effect of oxygen flow rate on electricity generation from sewage sludge comparison with other biomass. In Fig 3, the maximum flow rate of oxygen that were given high yield of electricity is 45ml/min. Reason behind that when we increase oxygen flow rate there will be increase in power generation due to acceptance of proton from anodic chamber and decrease in oxygen flow rate will decrease in acceptance of electron.

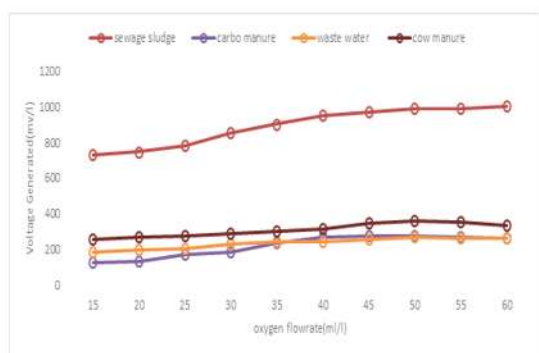


Figure 3: Oxygen flow rate vs voltage generation

Effect of pH value on voltage generation

Voltage generation from sewage sludge using MFC had effected from pH value. Different pH value were used to identify the effect of pH on voltage generation. The maximum yield of voltage 2500mv were obtained at the pH of 8.5. the effect of pH on voltage generation due to variation ionic form of active site. If there is decrease in pH value there will be decrease the activity of cellulosic nature of biomass so that's why pH below 7 must be tolerated.

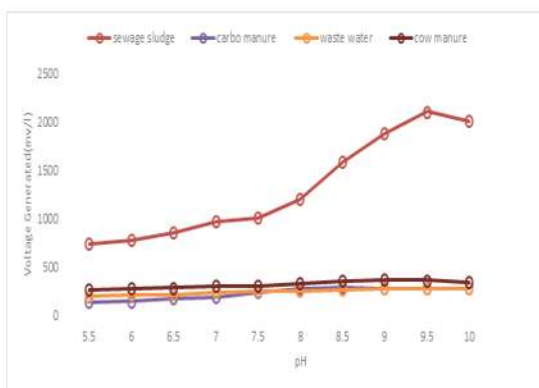


Figure 4: pH vs voltage generation

Effect of concentration of sample on voltage generation

Concentration of substrate has effect on power generation due to variation in organic matter present in biomass. As we know that organic matter present in sewage sludge mainly glucose, when we decrease the percentage of substrate there will be change in voltage output from MFC concentration has also effect the microbial activity of microbial fuel cell.

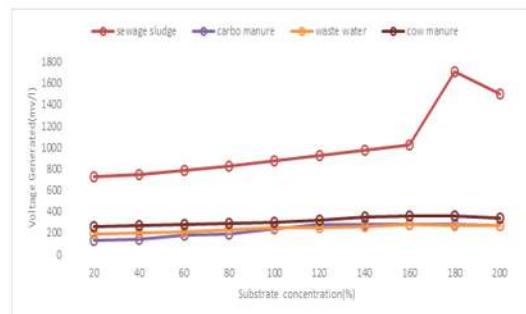


Figure 5: Concentration vs Voltage generation

Comparison of power output from the sewage sludge and from other biomass

Comparative study of different biomass were utilized for bio-electricity generation. Different biomass were studied to identify the suitable biomass for power generation. Fuel recovery from sewage sludge is a promising energy production method, which can simultaneously address energy issue and environmental concerns associated with waste treatment. so as for sewage sludge was concerned maximum yield of power generation obtained. Pre-treatment has shown significant improvement in MFC electricity productivity. Activated sludge and algae biomass are used as substrates in microbial fuel cell (MFC) to produce electricity. And also cattle dung as a substrate. As for other biomass were concerned gave the lesser power output due to the organic matter or we can say that lower in glucose concentration. Different types of biomass that were under study are cow manure, carbo manure, waste water and sewage sludge. The maximum power generation were obtained 2500mv/l using Sewage sludge as a biomass source and for other biomass concerned maximum power generation obtained from carob manure, cow manure and waste water 270mv/l, 229mv/l and 330mv/l respectively. The voltage output from waste water about to be 203 mV/l. it means that voltage generated from sewage sludge was maximum.

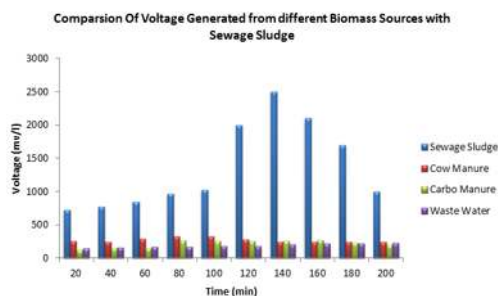


Figure 6: Comparison of different biomass used in MFC for power generation.

CONCLUSION

Different substrate were utilized to investigate the candidate substrate that produced handsome energy production. Among four different biomass Sewage has potential for power generation using MFC are cow manure, carbo manure, and waste water. The maximum electricity generation from sewage sludge is 2500mv/l. Other biomass sources maximum output are Carbo Manure (270mv/l), Cow Manure (229mv/l) and Waste Water (330mv/l). With the utilization of MFC for waste water treatment. We can also reduce waste from environment with decreasing pollutant from environment. Can treat waste water by using Microbial fuel cell. We can reduce waste from environment. The electricity generation from sewage is higher due to contain higher percentage of organic matter

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