Bioelectricity Production from Seafood Processing Wastewater using Microbial Fuel Cell

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Abstract - *Microbial Fuel Cell (MFC) is the latest technology that generates bioelectricity by converting chemical energy stored in the substrate (influent) through metabolic activity of microorganism under anaerobic condition. The recent energy crisis has generated interests to make use of energy generated from biomass, an alternative to conventional energy sources and also addressing energy and environmental problem. An attempt has been made in this project to a provide detail construction of dual chamber, microbial fuel cell setup along with preparation of salt bridge and methodology for generating power using seafood processed wastewater as substrate, determining the current and power generated at external resistance 1000 Ω. Comparative study was done on the effect of COD and Phosphate removal rate at different Hydraulic Retention Time (HRT) on MFC. The maximum voltage generated was 988 mV across 1000 Ω on corresponding maximum Current Density of 2996.664 mA/m² and maximum Power Density 2960.704 mW/m² for MFC. The COD and Phosphates removal efficiency for HRT of 15 days was 77.33 % and 84.32 %, respectively on MFC.*

Key Words: Energy, Wastewater, Microbial Fuel Cell

1. INTRODUCTION

In recent years energy consumption has been increased with dependence on fossil fuel such as coal, oil, and gases, which are developed billions of years ago within the earth, considered as a non-renewable source of energy. Several attempts have been made to make use of renewable sources such as sun, heat, waves and wind and as huge potential to provide a solution to the energy crisis and also the key factor to the future of energy, economic and food security. Because the population and new technology are always expanding, demand for energy is expected to increase year by year. A reliance on the current renewable energy sources alone will not sufficiently meet the required needs in the future. The Global consumption in 2010 was 520 quadrillion BTUs and is expected to increase by 56% in 2040. 16-19% of our energy consumption was contributed from renewable sources in 2012. With an increase in population by rapid urbanization, changing in consumption has led certainly led to a huge anthropogenic impact on planet earth. Fossil Fuel such as oil and gas will be depleted by 2042 and coal will be depleted by 2112. Recent studies prove that biodegradable waste can serve as the best source for energy generation and also control pollution and minimize the dependence on remaining fossil fuel. One of recent technology is Microbial Fuel Cell (MFC) that can degrade an organic waste and generate electricity through micro-organisms metabolic activity and then transfer yielded electron and proton. MFC is a promising technology that can meet increasing demand for energy. MFC has potential to generate 23.3 and 40 TW of electricity by 2025 and 2050 respectively from wastewater produce in India.

1.1 Microbial Fuel Cell

MFC is bioreactor in which microorganism acts as catalyst, converts the chemical energy stored in organic matter (substrate) into electrical energy. During this metabolic activity, oxidation takes place at anode which helps to generate electron and proton. This electron will flow towards cathode through an external circuit while proton will migrate through membrane to maintain electrical neutrality. MFC can be divided into three component of MFC, anaerobic chamber (anode), aerobic chamber (cathode) and cation exchange membrane.

Anode chamber is filled with substrate, mediator (optional), microorganism and the anode electrode as electron acceptor. It provides all necessary condition for growth of suitable microorganism and fed with growth material. Microbes in anodic chamber generates electron and proton, CO_2 is produced as oxidation product. The electron transfer is due to formation of biofilm on the surface of anode due to high columbic efficiency. Cathode chamber is the recombination compartment for the spent electrons, protons and oxygen molecules. It consists of electrode where Oxygen, Permanganate, Manganese dioxide, Iron, Potassium persulfate and Ferricyanide acts as electron acceptor. CEM is a widespread ion-penetrable separator. It acts as a separation between the anode and cathode chambers for the completion of the reaction. Power output in MFC is also influence by performance of PEM/CEM. It affects the system internal resistance and concentration polarization. The ratio of PEM surface area to system volume is important for power output. Internal resistance will decrease if PEM surface area increases. The most commonly used CEM is Nafion , Ultrex CMI-7000, Hyflon, Zirfon , Microporous filtration membranes, Salt bridge.

2. METHODOLOGY

A Dual chamber MFC was constructed, anode and cathode chamber was made up from Polypropylene (PP) plastic containers. The dimension of container was 160mm top diameter,140mm bottom diameter and 180mm in length, volume of container was 3 L. The working volume throughout experiment of both chambers was 1.5 L. For anaerobic condition cap of container was closed and for aerobic either open or aerator using aquarium air pump with air diffuser. The MFC reactor was separated into anode and cathode chambers by Salt Bridge. The CPVC pipe containing the salt-agar mixture was fixed between the two containers and behaved like the salt-bridge assisting in the proton transfer mechanism during the MFC operation. Carbon rods of size 10mm dia were used anode and cathode (electrodes) of Dual chamber MFC. Copper wire was winded along cylindrical surface of Carbon rod to collect and transfer electrons sufficiently.

2.1 MFC Setup, Inoculum And Operation

During the initial start-up period, the MFC reactors were inoculated using 1.5 L of anaerobic sludge from Uniroyal Marine Exports sewage treatment plant. Ethanol about 2mL and 0.1 N Sodium Hydroxide (NaOH) for pH maintenances was added daily. For operation of MFC, using anaerobic metabolism the anode chamber was purged with nitrogen to remove DO. The anode chamber was completely sealed and the setup was placed in a room at a temp of 27°C to 35°C. 2 g/L Sodium 2-bromoethanesulfonate Himedia salt was added in anode chamber for every 24 hour to inhibit the growth of methanogenic organism.

In cathode chamber with same working volume (1.5 L.) was filled with 50 mM potassium ferricyanide ($K_3Fe(CN)_6$) in phosphate buffer solution to make the pH 7. Air was sparged into it with the help of an air sparger using aquarium air Pump. The electrodes were connected to external resistance (R) 1000 Ω, cell voltage (V) across a 1000 Ω using a digital multimeter were recorded. All reactor operation was under Batch fed Mode. Both internal and external voltage were measured from digital multimeter. Current, Current density,Power and Power density were calculated.

2.2 Experimental setup

After inoculation for period of 30 days along with development of biofilm on surface of electrodes and achieving voltage stabilization. Salt bridge that used for the set up were collecting and transferring proton were exhausted. That exhausted salt bridge was removed and new salt bridge was provided. Seafood processed wastewater 1.2 L with 30% of activated (inoculated) sludge was filled in anodic chamber. The Catholyte was replaced with same working volume (1.5 L.) of 50 mM potassium ferricyanide ($K_3Fe(CN)_6$) in phosphate buffer solution to make the pH 7.

Fig -1: Experimental Setup of MFC during inoculation period

Fig -2: Exhausted Salt Bridge

3. RESULT AND DISCUSSION

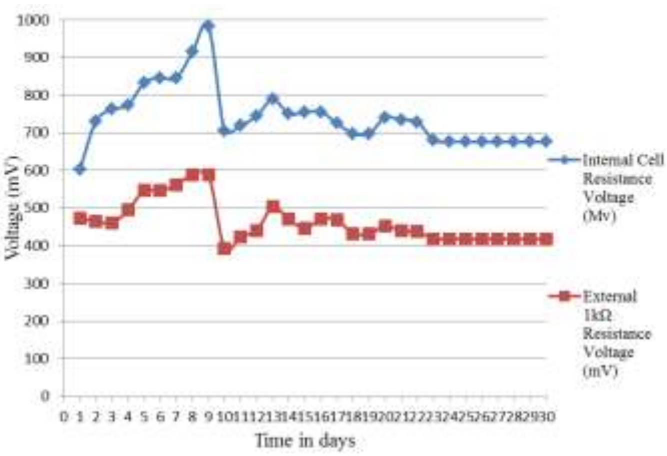

Chart -1: Voltage Generation of MFC during inoculation

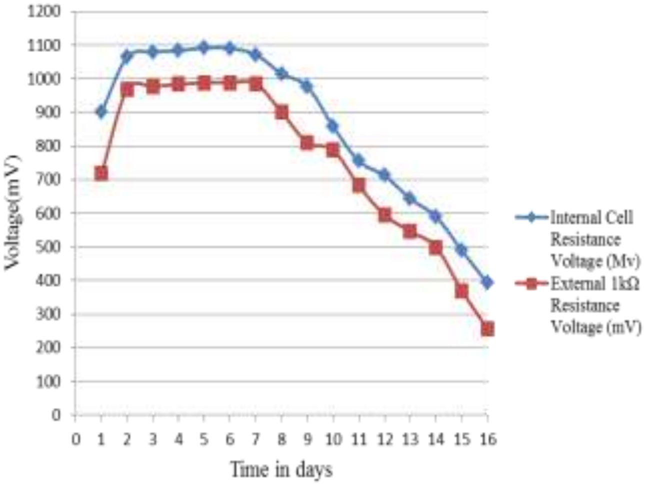

Chart -2: Voltage Generation using seafood processed waste water in MFC

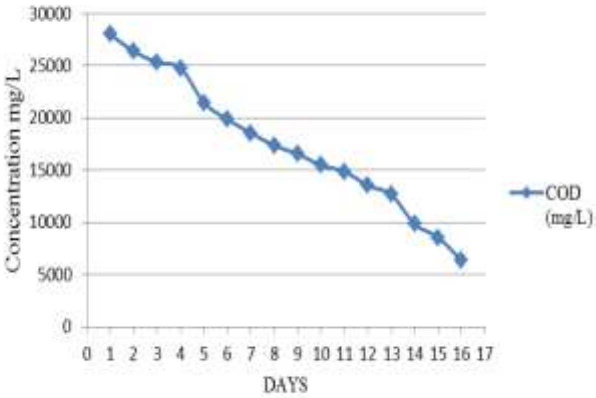

Chart -3: COD concentration mg/l of MFC

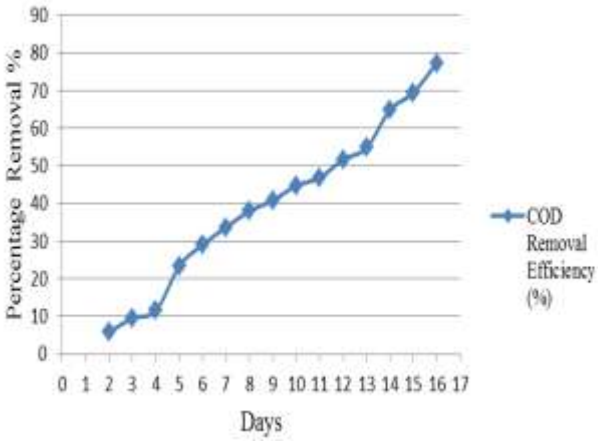

Chart -4: COD Removal Efficiency of MFC

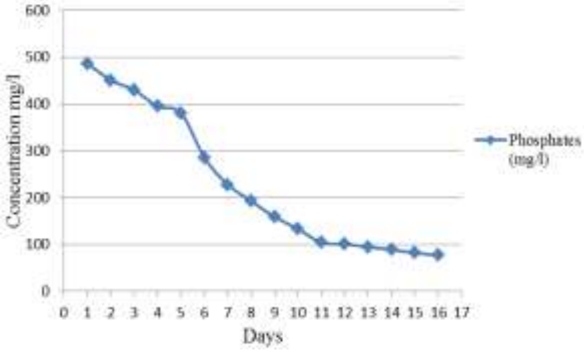

Chart -5: Phosphates concentration mg/l of MFC

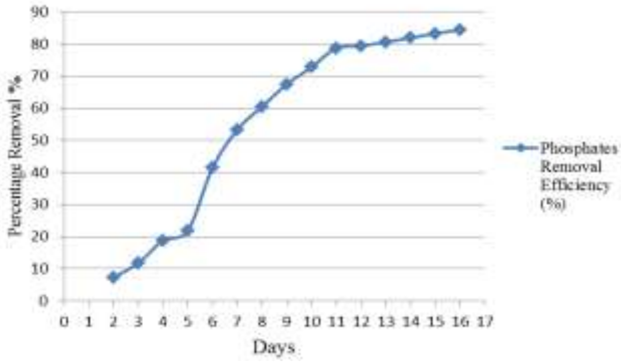

Chart -6: Phosphates Removal Efficiency of MFC

4. CONCLUSION

Bioelectricity was successfully generated using Seafood Processed Wastewater as a renewable source in a Dual Chamber MFC with Salt Bridge as PEM. The results found was very encouraging when compared to other MFC studies. High reproducibility in terms of voltage generation was achieved for batch fed MFC reactor.The MFC was operated with seafood processing wastewater was able to generate power continuously for almost 16 days.The maximum voltage generated was 988 mV across 1000 Ω on Day 5 with corresponding maximum Current Density of 2996.664 mA/m^2 and maximum Power Density 2960.704 mW/m^2 for MFC.The COD Removal Efficiency for HRT of 15 day was 77.33 % for MFC.The Phosphates Removal Efficiency for HRT of 15 day was 84.32 % for MFC. Salt bridge MFC is the simplest biological fuel cell that can be designed and studied. High COD removal from the substrate can be attributed to the adsorption of organics and extensive biofilm growth on the surface of the Carbon Rod. Along with power generation, the MFC revealed its ability to simultaneously treat seafood processed wastewater, and the efficiency of COD and Phosphates removal was shown to be influenced by HRT.

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