ELECTRICITY GENERATION BY MICROBIAL FUEL CELL USING AN ANODOPHILIC BIOFILM

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ABSTRACT

Microbial fuel cells (MFC) are capable of converting the chemical energy stored in the chemical compounds in a biomass to electrical energy with the aid of microorganisms. Microorganisms capable of oxidizing completely organic matter to CO_2 using electrodes as final electron acceptor are so-called electrogenics. In order to transfer electrons by conduction by electrogenic microorganisms to the electrode this have to be in direct contact with the electrode, being this a limitation to MFC due to limited surface area available in electrode. In the present study, a two-chamber MFC was used, with graphite electrodes, anodic electrode was inserted in a small piece of coyonoztle (*Opuntia imbricata*). MFC was operated in fedbatch mode during a period of 60 days, using glucose as carbon source glucose (3 g/L), three external loads were used (5.5 KΩ, 1 KΩ and 560Ω). Maximum voltage, current and power density was obtained for the case of 1 KΩ; 205.88 mV, 139.33 μA y 3.43 $\mu W \cdot cm^2$ respectably.

1.- Introduction

Microbial fuel cells (MFC), are bioelectrochemical devices capable of converting energy stored in organic matter to electricity using bacteria as biocatalyst, and are rapidly gaining acceptance as an alternative energy technology, due to its great versatility to use different substrates from renewable sources and convert them into harmless by-products with simultaneous production of electricity. Production of electricity by MFC happens when bacteria extracts electrons from these substrates and migrate to the anode (negative terminal) in the anodic chamber and flow to the cathode (positive terminal) trough a conductive material and a resistor, or operated under a load [4]. This Electrons can be transferred to the anode by electron mediators or shuttles [7], by direct membrane associated electron transfer [4], or conduction by nanowires [7] produced by the bacteria.

In the conduction mechanism, were bacteria transfer electrons to the anode from their membrane-bound electron carriers to the electrode via conductive materials in the biofilms matrix creating what has been called biofilms anode. The matrix of EPS of at least some anode-respiring biofilms contains highly conductive nanowires that extend for tens of micrometers [4]. In the model describe by it predicts how fast the anode biofilm grows, how fast substrate is oxidized and how much current is generated under different conditions. If the biofilm is too thin, there are insufficient bacteria to generate a substantial current, but if the biofilm is too thick, the current is reduced because electrons cannot reach the anode. In more conductive biofilms, other factors, such as substrate mass transport, become important. The authors suggest that controlling biofilm thickness, by using a turbulent environment in the microbial fuel cell to regulate the detachment of cells from the biofilm, might be one method of maximizing the current that is produced [6, 8].

In the present study, a two-chamber MFC was used, with graphite electrodes, the anodic electrode was inserted in a small pieces of a dried stem of cactus plant *Opuntia imbricata*. MFC was operated in fedbatch mode during a period of 60 days, using glucose as carbon source glucose (3 g/L), three external loads were used (5.5 KΩ, 1 KΩ and 560Ω).

2.- Materials and Methods

Experimental set-up: The two-chamber MFC were constructed with two plastic bottles with a volume of 1000 ml each. Plastic bottles were perforated and attached an inner screw thread joint to each bottle. An external thread joint (4 in length) was use to constructed the agar salt bridge (agar 3%, KCl 100 Mm). Graphite rods (Ø 0.8 cm × 4 cm length, surface area 10.55 cm^2) were used as electrodes for both chambers and connected using coated copper wire 22 gauge and sealed with silicon.

Support media. Small cylindrical pieces of dried stems of *Opuntia imbricata* were cut [(6 cm length, 5 cm O.D. 2.5 cm I.D.) ± 0.2 cm] and meticulous rinsed and washed with fresh water, subsequently it was washed with distilled water to remove any present matter, and finally it was subject to sterilization for a period of 1 hour. An electrode was inserted in the support media.

Biofilm growth. Support media with electrode was placed in a 1 litter container and 250 ml of anaerobic sludge obtained from a UASB reactor and 500 ml of medium containing glucose as the electron donor (3 g L^{-1} = 850 mg COD L^{-1}), in a mineral medium $Na_2H_2PO_4.2H_2O$ (0.53 g L^{-1}), NH_4Cl (0.3 g L^{-1}), $MgCl_2.2H_2O$ (0 .1 g L^{-1}), $CoCl_2.6H_2O$ (0.08 g L^{-1}), $NiCl_2.6H_2O$ (0.02 g L^{-1}) and $ZnCl_2$ (0.001 g L^{-1}) was added. After 4 weeks assembly of support media and electrode was withdraw from the container and placed in the MFC. Cathodic solution $KMnO_4$ (20 Mm) was used. Evaluation of MFC was conducted at room temperature (18 - 23°C).

Data acquisition and measurements. Voltage (*V*) was measured every 60 minutes with a digital multimeter with data logging capacity (FLUKE 287), current (*I*) was calculated according to Ohm's Law, *I*) *V*/*R*, where *V* is the measured voltage and *R* is the external resistance (5.8, 1 and 0.560 KΩ) . Maximum power density was determined as described by Logan *et al*., 2006, $P= VI/A$; where *A* (m^2) is the surface area of the electrode. The glucose overall removal as COD was determined as describe by Rodriguez-Martinez *et al*., 2005 [6].

3.- Results and discussions

Voltage and current generation in MFC. MFC was operated under fedbatch and an external resistance was always present for the entire duration of the experiment. At the beginning for the first 672 hours the external resistance was 5.8 KΩ. During this time the voltage generated by the MFC never passed the 100 mV with a maximum voltage of 94.1 mV as showed in figure 1. After 200 hours MFC potential started to increase reaching its maximum at 490. After MFC was fed at 462 hours, it reached its maximum, and a drop in the MFC potential was observed. This could be attribute to a possible shift in microbial community as suggested by Reguera, et al, 2006 [4], they found that many cells were not actively contributing to current production and current production was relatively low to the amount of biomass on the anode [1, 4, 5].

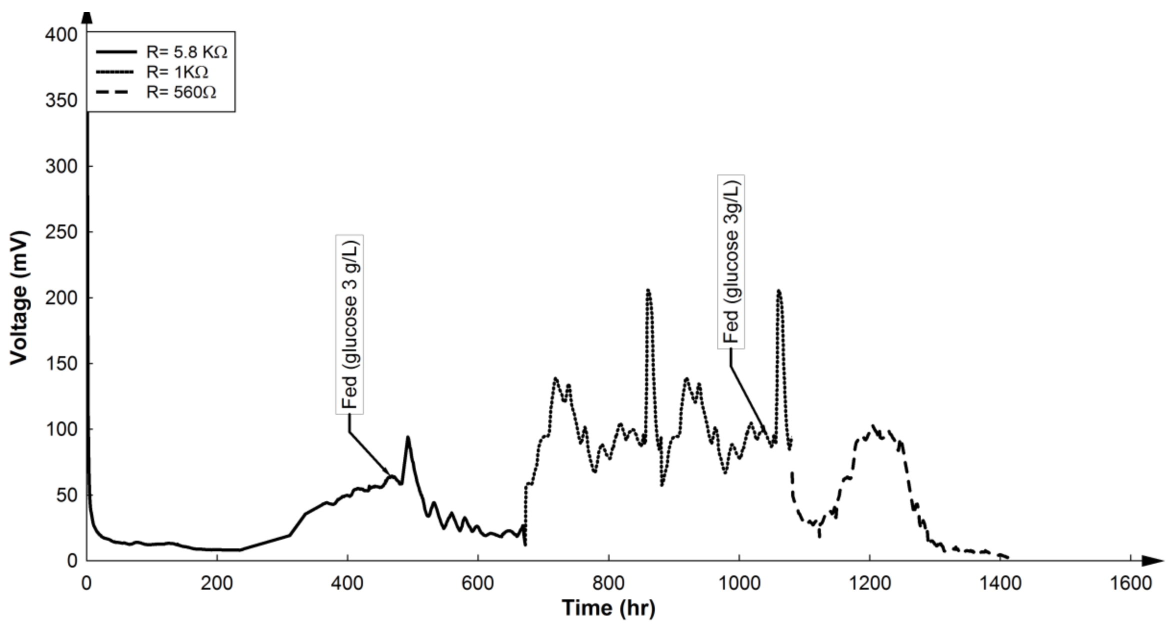

Figure 1. Voltage generation vs. time using three different external loads (5.8, 1, 0.560 KΩ). Arrows show when MFC was fed.

As expected, when external resistance was changed to 1 KΩ an increase in the anodic potential was observed (Figure 1 and 2) this could be explained due to stimulation of the reoxidation of any electron mediators that may be present in the system, hence facilitating the electron transfer from bacteria to such mediators. In general, the use of smaller external resistance caused an increase in electron flow [1, 8].

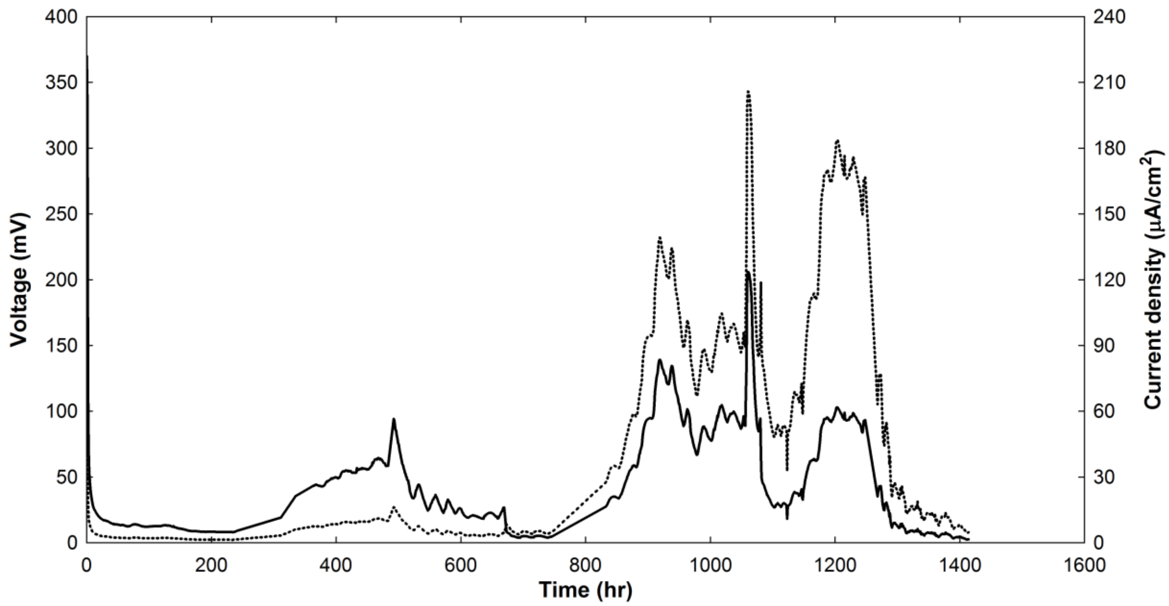

Figure 2. Voltage and current density generated by MFC microbial fuel cell during downward and upward step-changes of external resistance.

The maximum power density reported here is modest compared with MFC using a proton exchange membranes, due to higher internal resistance of the salt bridge system as describe by Min *et al.*, (2005), where comparison between MFC with two different selective membranes were conducted (proton exchange membrane vs. salt bridge), the low power output by the MFC with a salt bridge is directly attributed to the high internal resistance (19920 ± 50Ω) compared to the low internal resistance by the MFC with proton exchange membrane (1286± 1Ω). However, early reports by our research group, suggests the results obtained in this study are found to be very promising for a salt bridge two-chamber MFC [9].

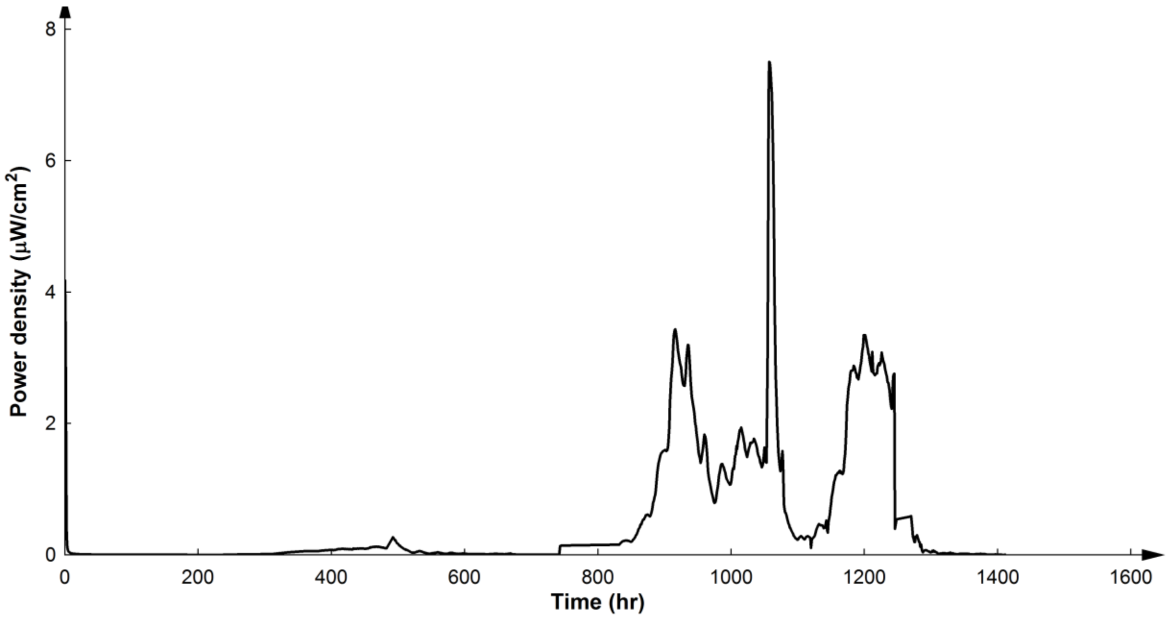

Figure 3. Power production at different external resistances (5.8, 1 and 0.560 KΩ) over time.

4.- Conclusions

In order to be consider a practical use giving power output over long periods of time MFC will have to be converted to continuous flow and employing substrates such as wastewater and variety of organic pollutants. The use of expensive catalysts for the cathode must also be avoided, being oxygen from free air the ideal catalyst. In such systems, substrate and other nutrients will be continuously supplied to the bacteria and furthermore, there will be no waste product accumulation as these will be constantly driven out of the system. Designing MFC to operate in a continuous mode is a challenge that will have to be addressed according to the type of MFC under consideration.

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