Microbial Fuel Cells as Life Biosensors

Ximena C. Abrevaya[1], Pablo J. D. Mauas [1,*] and Eduardo Cortón [2,*]

[1]Instituto de Astronomía y Física del Espacio (IAFE), UBA-CONICET. Pabellón IAFE (1428) Buenos Aires, Argentina. [2]Grupo de Biosensores y Bioanálisis, Departamento de Química Biológica, Facultad de Ciencias Exactas y Naturales, UBA, Pabellón II, 4to piso (1428). Buenos Aires, Argentina.
*Consejo Nacional de Investigaciones Científicas y Técnicas, CONICET. Buenos Aires, Argentina.
E-mail: abrevaya@iafe.uba.ar

Abstract

In this work we show the capacity of bioelectrochemical systems as Microbial Fuel Cells (MFCs), to be used as microbial life sensors based on metabolism as a common feature of life. Microorganisms being representatives of different domains of life were used in the anode: *Saccharomyces cerevisiae* and *Natrialba magadii,* an eukaryotic organism and an halophile archaeon, respectively, or a mixed community of microorganisms from humus soil. We demonstrate that the power and current density values measured in MFCs using microorganism cultures or soil samples in the anode are much larger than those obtained using sterilized cultures or soil samples, respectively. Therefore, our results show that MFCs have the potential to be used to detect microbial life, and could be used as sensors to detect microbial life *in situ.*

Keywords: metabolism, sensor, microbial fuel cell, microorganism, bioelectrochemical systems

Introduction

Microbial Fuel Cells (MFCs) are bio-electrochemical systems originally designed and applied to electrical power generation. In these devices, the power source is given by biocatalysts such as microorganisms, which as part of their metabolic process, release electrons that supply the electric current production, that can be easily measured if an adequate external resistor is incorporated in the electric circuit.

At present, there is much work done with MFCs, with multiple combinations of electrode material and microorganisms [1], [2], [3].

In the conventional configuration, MFCs have a cathode and anode chamber, which are connected through a cation exchange membrane (such as Nafion®) (Fig 1). Usually, the anode is biotic and the cathode abiotic, since the anolyte contain microorganisms and catholyte is composed by an oxidizing agent, as oxygen or ferricyanide, among others. In the anode, electrons are released due to the oxidation of organic material which is carried out by the microorganisms. This activity is proportional to the metabolic process and therefore is related to heterotrophic metabolisms.

Since metabolism is a widespread characteristic of all kind of life on Earth and could be a common feature of all living system including extraterrestrial life [4], MFCs could be used as life detection sensors based on metabolic activity.

In the present work we show the capacity of MFCs for the detection of heterotrophic metabolisms, and its potential use to the *in situ* search for extraterrestrial and terrestrial life.

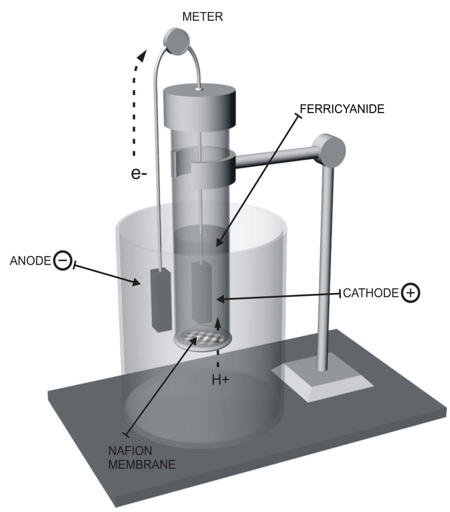

Figure 1. Scheme of the MFC employed in the experiments.

Materials and Methods

MFCs were constructed using polystyrene cylinders. Inside, the catholyte, contained a solution made of ferricyanide (8.4 g L-1) dissolved in an appropriate buffer solution, according to the sample to be measured. At the bottom a Nafion® membrane (area 0.38 cm2 DuPont, Wilmington, DE) allows, proton exchange between the inside and the outside media. Outside the tube, the anolyte, contained a sample of the microorganisms to be analyzed (culture or soil), which in the control experiments were replaced by sterilized culture or soil.

The electrodes, cathode and anode, were made of Toray® carbon paper (TGP-H-120, density, 0.45 g cm^{-3}, porosity 78%, Toray Industries) for microbial culture experiments and graphite reinforced with carbon (0.7 HB pencil lead, Faber Castell, Brasil) for soil experiments (the total area was 5.5 cm^2 for carbon paper and 3.76 cm^2 for graphite reinforced with carbon). Pure cultures of microorganisms (*Saccharomyces cerevisiae* and *Natrialba magadii,* an eukaryotic organism and an halophile archaeon, respectively) or a mixed community of microorganisms from humus soil, were placed in the anode compartment. Together with the corresponding experiments sterilized culture or soil samples were tested.

To study the MFC behavior the potential (E, Volts) was measured at open circuit using a digital tester and different resistances ranging from 98Ω to 100 kΩ as an external load. The electrical current (I, Ampere) was calculated according to Ohm's Law and power (P, Watt) was calculated according to P=I.E.

Power and electrical current were normalized using the electrode area and were expressed as power and current density, (p) in µWatt cm^{-2} and (j) in µAmpere cm^{-2} respectively.

Results

The results obtained for each microorganism are summarized in Figure 2 and 3. In Fig. 2 are shown the power density values obtained for each sample. It can be seen that in all the experiments power densities were larger when microorganisms were present in the anode than in the corresponding sterilized samples. The current density values at maximum power density showed the same behavior (Fig. 3).

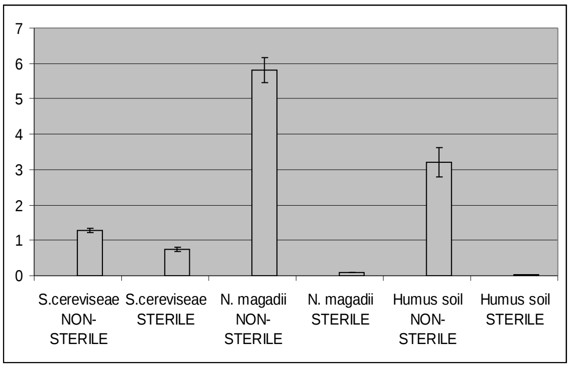

Figure 2. Comparison of power density values (Mean ± SE) obtained from culture and soil experiments.

.

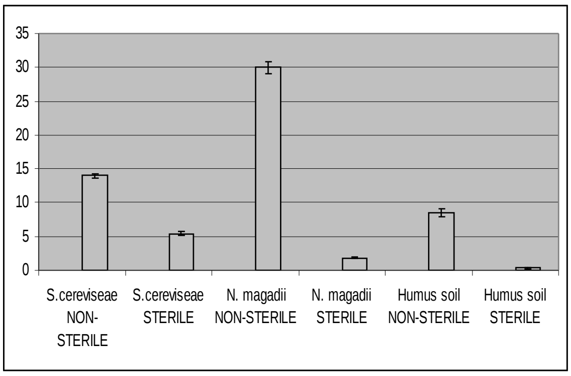

Figure 3. Comparison of current density values at maximum p (Mean ± SE) obtained from culture and soil experiments.

Conclusions

We demonstrate that the power and current density values measured in MFCs using microorganism cultures or soil samples in the anode are much larger than those obtained using sterilized cultures or soil samples, respectively. This is due to the fact that, in the absence of biocatalysts, the electrons which are transferred through the circuit are limited by the anodic reaction, which depends upon reduced substances that are present at the beginning of the experiment and then exhausted with time.

In particular, we found that this is valid even for an extremophile organism as halophile archaea, usually proposed as possible inhabitants of extraterrestrial environments [5]. Therefore, our results show that MFCs have the potential to be used as sensors to detect microbial life *in situ,* for terrestrial and extraterrestrial environments. However it would be desirable to compare these results with other obtained using a different methodology.

References

[1] Rabaey, K. and Verstraete, W. Trends in Biotechnology No. 23, pp 291-298, 2005

[2] Bullen, R.A., Arnot, T.C., Lakeman, J.B. and Walsh F.C. Biosensensors and Bioelectronics No. 21, pp. 2015-2045, 2006.

[3] Davis, F. and Higson, P.J. Biosensors and Bioelectronics No. 22, pp. 1224-1235, 2007.

[4] Nealson, K.H., Tsapin, A., Storrie-Lombardi, M. International Microbiology No.5, pp. 223-230, 2002.

[5] Cavicchioli, R. Astrobiology Vol 2, No. 3., pp.281-292, 2002.