ELECTRICITY GENERATION BY MEANS OF MICROORGANISMS FROM DIFFERENT PHYSIOLOGICAL GROUPS

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Abstract: *Microorganisms from three different physiological groups (sulphate-reducing, iron (III)-reducing and fermenting bacteria) were used to generate electricity by means of two-sections microbial fuel cells. The power generation by this system varied within a large area (from 250 to 3200 mW/m^2) and depended on the type,form and quantity of the organic donors of electrons, the enzymatic activities of the microorganisms in the anodic section and the efficiency of aeration in the cathodic section.*

Keywords: MICROBIAL FUEL CELL, ELECTRICITY GENERATION, SULPHATE REDUCING BACTERIA, IRON-REDUCING BACTERIA, FERMENTING BACTERIA

1. Introduction

The ability of some microorganisms to generate electricity in constructed fuel cells is connected with the microbial ability to transfer electrons from different organic substrates to the surface of anodic electrodes located in the anoxic sections of the relevant fuel cells. Some of these microorganisms (mainly bacteria and archaea) are able to form biofilms on the anodic surface and to transfer the electrons directly, through microscopic pipes located in the pili on the microbial surface. The most active microorganisms using this mechanism are some bacteria possessing the so called anaerobic iron respiration. These bacteria are typical heterotrophs able to remove electrons from some organic compounds and to transfer them via the microbial respiratory chains to ferric ions acting as final electron acceptors. The most studied from these bacteria are some species related to the genera *Geobacter* and *Shewanella.* They are able to form stable biofilms on the anodic electrodes in the constructed microbial fuel cells. In these cells the electrons are removed from the anode by means of wires (usually consisting of copper) and are transferred to contact with a suitable resistance located outside the anodic section. As a result of such treatment, a postion of the chemical energy of electrons is transferred to electricity and the electrons reach the aerobic cathodic section in which they react with the protons to form water molecules (Rabaey and Verstraete, 2005; Du et al., 2007; Lovely, 2008).

Apart from the Fe^{3+}-reducing bacteria, microorganisms (also bacteria) related to two other physiological groups are also used in investigations for electricity generation: sulphate-reducing bacteria (mainly of the genera *Desulfovibrio, Desulfobacter* and *Desulfomonas*) and fermenting bacteria (mainly of the genera *Bacillus, Pseudomonas* and *Clostridium).*

Some data about our investigations on the possibility of strains related to different species from the three physiological groups mentioned above to generate electricity by means of identical fuel cells are shown in this paper.

2. Materials and Methods

The ability of different microorganisms to generate electricity was tested by means of a variant of the microbial fuel cells of the type which was selected on the basis of the results from several previous experiments. The cells used in this study were plexiglas cylindrical columns 80 cm high, with an internal diameter of 12 cm. A perforated slab graphite – Mn^{4+} anode and a graphite – Fe^{3+} cathode were located in the bottom and in the top section of the column, respectively. The two sections were separated by a permeable barrier of 5 cm thickness consisting of a 2.5 cm layers of glass wool and a 2.5 cm layer of glass beads. The feed stream containing the potential energy sources for the microorganisms was supplied to the bottom anodic section of the column and the effluents passed through cathodic section and continuously exited at the top. Air was injected during the treatment to the cathodic section.

The feed streams, i.e. the nutrient solutions used for the cultivation of the microorganisms intended for generation of electricity by the microbial fuel cells were as follows: for the sulphate-redusing bacteria – the nutrient medium of Widdel and Pfening (Widdel, 1988), for the ferric iron-reducing bacteria – the nutrient medium of Kostka and Nealson (1988) and for the fermenting bacteria – in the standard meat-peptone bouillon.

The quality of the waters treated by the microbial fuel cells was monitored at the inlet and the outlet of the relevant fuel cell. The parameters measured included: pH, Eh, dissolved oxygen, chemical composition, temperature, voltage of the open circuit and power. The isolation, identification, and enumeration of microorganisms were carried out by the classical physiological and biochemical tests (Karavaiko et al., 1988) and by the molecular PCR methods (Sanz and Köchling, 2007; Escobar et al., 2008).

3. Results and Discussion

The comparative experiments performed during this study revealed that strains related even to one and the same taxonomic species can differ considerably from each other with respect to their ability to generate electricity under identical experimental conditions (Tables 1 – 3). This is quite normal having in mind that the ability of such microorganisms to degrade one and the same organic substrate, i.e. to extract electrons from it, is often also quite different. Furthermore, in some cases strains related to different physiological groups have a very similar ability to generate electricity even under the presence of different concentrations of the relevant organic substrates. In most cases very essential for increasing the electricity generation was the efficient aeration in the cathodic section. It was possible to conclude that the power generation by such systems depends on the type, form and quantity of the organic donors of electons, the enzymatic activities of the microorganisms in the anodic section and the efficiency of aeration in the cathodic section.

Table 1. *Efficiency of electricity generation by means of sulphate-reducing bacteria*

Sulphate-reducing bacteria	COD, mg O_2/l.h	Power, mW/m^2
Desufovibrio spp.	620 – 1630	420 – 1700
Desulfobacter spp.	550 – 1270	370 – 1400
Desulfomonas spp.	480 – 1040	320 -1200
Mixed populations	410 - 1720	410 - 1550

Table 2. *Efficiency of electricity generation by means of Fe (III)-reducing bacteria*

Fe (III) - reducing bacteria	COD, mg O_2/l.h	Power, mW/m^2
Shewanella loihica	590 – 1410	410 – 1400
S.odeinensis	510 – 1270	350 – 1200
S.putrefaciens	440 – 1040	320 – 970
S.alga	370 – 990	350 – 950
Geobacter metallireducens	640 – 1450	420 – 1000
G.ferrireducens	510 – 1090	320 – 990
G.sulfurreducens	440 – 1020	300 – 950
G.hydrogenofilus	390 - 820	320 - 790

Table 3. *Efficiency of electricity generation by means of fermenting bacteria*

Fermenting bacteria	COD, mg O_2/l.h	Power, mW/m^2
Bacillus subtilis	680 – 1700	410 – 1630
Bacillus spp.	710 – 1670	410 – 1540
Pseudomonas sp.	520 – 1400	280 – 1250
Clostridium spp.	410 – 1250	250 – 1400
Mixed populations	350 - 1450	370 - 1520

Similar conclusions were made on the basis of the results from the experiments in which natural microorganisms present in the organic substrates (compost from plant leafs, manure of different origin, sawdust) were used to generate electricity (Table 4).

Table 4. *Electricity generation from different organic substrates by means of microorganisms inhabiting these substrates*

Organic substrates	Initial COD, mg O_2/l.h	Microbial cells, maximum numbers/g	Power, mW/m^2
Compost from plant leafs	210 - 1040	3.10^8	500 - 2100
Manure of different origin:			
- birds	205 – 910	3.10^8	450 – 1900
- sheeps	235 – 1090	6.10^8	600 – 2300
- cattle	320 - 1220	$>8.10^8$	800 – 3200
Saw-dust from trees	170 - 620	1.10^8	500 - 1400

However, it must be noted that after several repetitions of the experiments using inocula from the relevant preceding test the compositions of these inocula changed, in most cases, to different positive extents. This approach can be accepted as a way for selecting some electricity active microorganisms.

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