Energy Conversion and Management 75 (2013) 256–262

Contents lists available at SciVerse ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Assessment of bioelectricity production in microbial fuel cells through series and parallel connections

Tahere Jafary [a], Mostafa Rahimnejad [a,*], Ali Asghar Ghoreyshi [a], Ghasem Najafpour [a], Fahime Hghparast [a], Wan Ramli Wan Daud [b]

[a] Biotechnology Research Lab., Faculty of Chemical Engineering, Noshirvani University of Technology, Babol, Iran
[b] Institute of Fuel Cell Technology, University Kebangsaan Malaysia, 43600 UKM Bangi, Malaysia

ARTICLE INFO

Article history:
Received 19 March 2013
Accepted 21 June 2013

Keywords:
Microbial fuel cell
Series and parallel connection
Polarization and voltage curves
Internal resistance

ABSTRACT

Microbial fuel cell (MFC) units which are connected in series and parallel, may increase MFC performance in forms of voltage and current respectively. In this research three individual MFC units were connected with different concentrations (10, 20 and 30 g l^{-1}) of glucose, fructose and sucrose. Generated power and current were analyzed through polarization and voltage curves. Parallel connections of three units, which fed with 10 g l^{-1} of each substrate, resulted in voltage and power densities of 0.65 V and 72.77 mW m^{-2}, respectively. This configuration produced current density of 191.36 mA m^{-2} which was approximately three times higher than a single unit. By similar configuration but in series, produced voltage was increased to 1.78 V, as long as power and current densities were about at the same level of one single unit (52.35 mW $m^{-2}$and 57.6 mA m^{-2}). Substrate concentration enhancement to 20 and 30 g l^{-1} resulted in the same magnitude of increase for cell performances compared to the single unit results. Serial connection of 20 g l^{-1} of three substrates (glucose, fructose and sucrose) showed the highest results compared to other understudied substrate concentrations; 109.45 mW m^{-2} of power density, 98.14 mA m^{-2} of current density and 2.042 V as voltage. Shift of MFC configuration to parallel connection demonstrated 381.44 mA m^{-2}, 128.72 mW m^{-2} and 0.68 V as current, power densities and voltage respectively. This configuration corresponds to the lowest calculated internal resistance.

1. Introduction

As petroleum is depleted, energy crisis encouraged researchers to investigate for alternative sources of energy. Moreover, using of fossil fuels may cause environmental pollution. Clean fuels, significantly biofules, as new sources of energy without any pollution are suitable replacements of traditional fossil fuels [1,2]. Extensive researches focused in this regard during last decades globally.

Microbial fuel cell (MFC) is one of the newest technologies to produce energy from different sources of substrates [3,4]. When Luigi Galvani observed electric response by connecting frog legs to a metallic conductor in the latest eighteenth century, new idea of generating energy from biological route, was developed. This idea was intensified by demonstration of current flow between two electrodes emerged in a bacterial culture [5,6]. Expanding further aspects of this idea in later decades established noble concepts of a new technology designated as MFC.

Substrate is regarded as one of the mainly essential biochemical factors affecting power generation in MFCs. MFCs are able to utilize different sources of chemical matters for production of bioelectricity. Recently MFC technology is considered as a new method for production of energy along with wastewater treatment simultaneously [7,8]. Microorganisms are capable of converting organic or inorganic compounds into electrical power [9]. The process occurs through metabolic activity of microorganisms at ambient pressure and temperature [10].

One of disadvantages of MFC is low power density. Recently, more extensive studies have been performed to bring MFC technology into industrial stages; in form of novel configuration [11,12], such as new trends for omitting membrane [13], new surface morphology of electrodes [14–16] and substrate types and concentrations [11,17–19].

Actually practical applications of single MFCs are restricted due to low power and voltage, which never exceed the theoretical one (1.14 V) [20,21] and makes MFC in form of individual cell inapplicable. Various reactor designs have been studied so far to overcome MFCs' limitation for practical applications [22–24].

Each single cell of MFC can be assembled in parallel or series to produce higher operating voltage, power and current densities

* Corresponding author. Tel.: +98 111 323 4204; fax: +98 111 321 0975.
E-mail addresses: Rahimnejad@nit.ac.ir, Rahimnejad_mostafa@yahoo.com (M. Rahimnejad).

0196-8904/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enconman.2013.06.032

[25]. By combining proper numbers of MFC in parallel or series, the desired current or voltage could be obtained beyond special applications [26]. When several single cells are connected in parallel, voltage stables in an average amount and current increases [22,27].

The present study focused on evaluation of MFC performance for different concentrations of three substrates at anode chamber. Meanwhile influence of the electrical circuit (series or parallel) on the power, voltage and current outputs of each individual and overall connected unit were investigated. Various binary and ternary connections between equal concentrations of glucose, fructose and sucrose were analyzed.

2. Materials and methods

2.1. Culture and medium

Saccharomyces cerevisiae PTCC 5269 was supplied as active biocatalyst by Iranian Research Organization for Science and Technology (IROST), Tehran, Iran. The microorganism was grown in an anaerobic jar. The prepared medium for seed culture consists of yeast extract, NH_4Cl, NaH_2PO_4, $MgSO_4$ and $MnSO_4$: 3, 0.2, 0.6, 0.2 and 0.05 g l^{-1}, respectively. Glucose, fructose and sucrose as basic carbon sources and electron donors were added to the medium with concentrations in the range of 10–30 g l^{-1}. The medium was sterilized and autoclaved at 121 °C and 15psig for 20 min.

The pH meter, HANA 211 (Romania) model glass-electrode was employed to measure pH values of the aqueous phase. The medium pH was initially adjusted to 6.5 and the inoculums were introduced into the media at ambient temperature. The initial pH of the working solution was adjusted by addition of diluted HNO_3 or 0.1 M NaOH solutions. The inoculated cultures were incubated at 30 °C. The bacteria were fully grown for duration of 24 h in 100 ml flask without any agitation. All chemicals and reagents used for the experiments were analytical grades and supplied by Merck (Darmstadt, Germany).

2.2. MFC construction and operation

The fabricated individual cells in laboratory scale were made of Plexiglas material. The volume of each chamber (anode and cathode chambers) was 800 ml with working volume of 600 ml (75% of total volume). The sample port was provided for anode chamber, wire point inputs and inlet port. Electrodes of individual MFCs were electrically connected in parallel or series by using copper wires. The selected electrodes in MFC were graphite felt ($80 \times 45 \times 2$ mm). Proton exchange membrane (PEM; NAFION 117, Sigma–Aldrich) was used to separate two compartments. Nafion area separating the chambers was 9 cm^2. Nafion as a PEM was subjected to a course of pretreatment to take off any impurities. The membrane pretreatment started with boiling the film in 3% H_2O_2 for 1 h, washed with deionized water, 0.5 M H_2SO_4, and then washed with deionized water. The anode and cathode compartments were filled with deionized water when the biological fuel cell was not in use to maintain and preserve the membrane for good conductivity. Natural Red and Ferricyanide with the concentrations of 100 and 300 μmol l^{-1} were used as mediators in anode and cathode of each MFC unit, respectively. Nine individual and similar cells were fabricated and used in different connection modes. Schematic diagram of ternary connection of fabricated MFCs in series and parallel modes are presented in Fig. 1.

2.3. Analytical methods and calculations

Difference between cathode and anode potentials (*V*) was monitored and recorded every 30 min using a data acquisition system, while the current (*I*) through the cell was calculated with respect

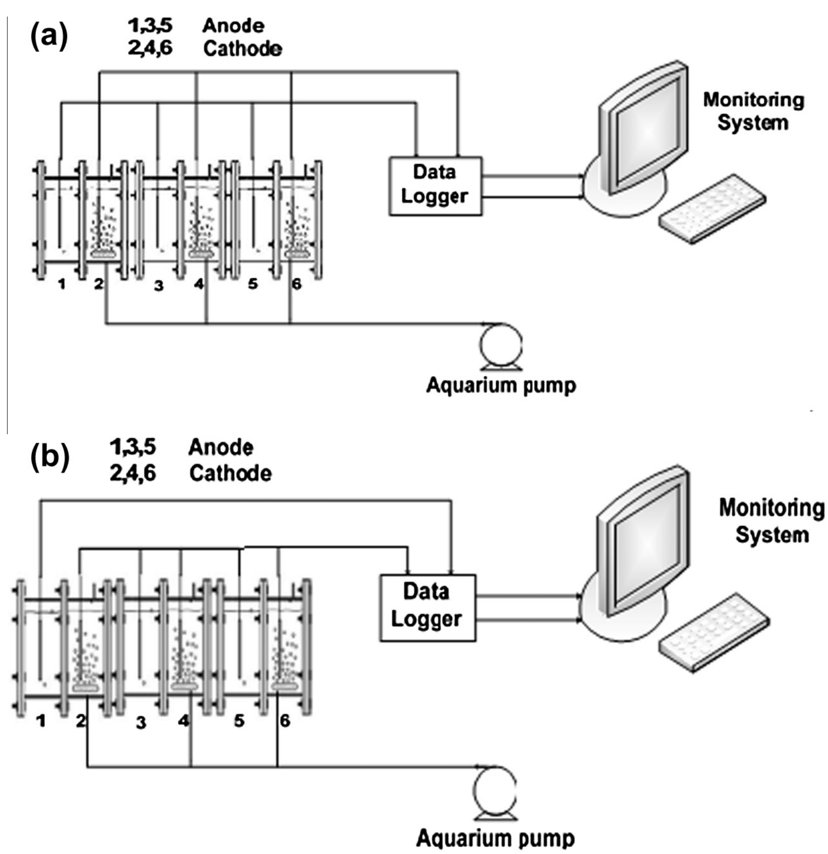

Fig. 1. Schematic diagrams of (a) parallel and (b) series closed circuits with three typical two-chambered MFCs .