Fuel 117 (2014) 697–703

Contents lists available at ScienceDirect

Fuel

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

Use of artificial neural network for the prediction of bioelectricity production in a membrane less microbial fuel cell

Ali Tardast [a], Mostafa Rahimnejad [a,*], Ghasem Najafpour [a], Ali Ghoreyshi [a], Giuliano C. Premier [b], Gholamreza Bakeri [a], Sang-Eun Oh [c]

[a] Biotechnology Research Lab., Faculty of Chemical Engineering, Noshirvani University, Babol, Iran
[b] Sustainable Environment Research Centre (SERC), Faculty of Advanced Technology, 16 University of Glamorgan, Pontypridd CF37 1DL, United Kingdom
[c] Department of Biological Environment, Kangwon National University, 200-701 Chuncheon, Republic of Korea

HIGHLIGHTS

- This study demonstrates the use of membrane-less microbial fuel cell.
- The maximum generated voltage and power were 850 mV and 80.12 mW m^{-2}, respectively.
- Artificial neural network was applied for prediction of bioelectricity production from glucose.
- Such a membrane-less microbial fuel cell has high scalability and low material cost.

ARTICLE INFO

Article history:
Received 17 December 2012
Received in revised form 16 September 2013
Accepted 17 September 2013
Available online 10 October 2013

Keywords:
Microbial fuel cell
Bioelectricity
Power density
Artificial neural network

ABSTRACT

Microbial fuel cells (MFCs) are the most recent bioelectrical devices which convert biodegradable organic matters to bioelectricity in presence of active biocatalyst. This system can generate electrons (e^-) and protons (H^+), in which electrons transfer from anode compartment to cathode chamber through an external circuit. MFC architect is one of important factor that effects on MFC performance. In this study, new membrane-less MFC was fabricated. Mixed culture of anaerobic microorganisms was collected from dairy wastewater effluents (Gella, Amol) as active biocatalysts in anode chamber. Initial open circuit voltage was less than 500 mV. Maximum open circuit voltage of 750 mV was achieved after 95 h of operation time. Maximum obtained power density was 80.12 mW/m^2. Artificial neural network was applied for the prediction of bioelectricity production from glucose as electron donors. Fabricated network was presented by multilayer perceptron and had a good ability for prediction with high correlation coefficient ($R^2_{\text{average-ANN}} = 0.99$).

1. Introduction

Fossil sources of energy have several disadvantages such as climate change, environmental pollutions, creating more economical crisis as the costs having increasing trends. Fossil sources while abundant are exhaustible and alternative sources of energy are both socio-economically and environmentally attractive. Relatively recent developments in direct generation of electricity from living bacteria, such as the avoidance of toxic mediators and increasing power densities, have advanced the field of Microbial fuel cells (MFCs). MFCs convert low grade biodegradable organic and inorganic materials to bioenergy directly in the form of electricity and the concept has been extended to include reduction reactions at a cathode, using electrons in, e.g. proton reduction to hydrogen gas [1–4]. MFCs have the ability to produce electricity from waste materials, thus can simultaneously treat wastes such as wastewaters [5,6]. Different biodegradable substrates such as glucose, sucrose, acetate and biomass material, have been used for electricity production in MFC [6]. Microorganisms in an anode compartment can degrade substrate into electron, proton and CO_2 [7]. The operating mechanisms of MFCs are well presented in several studies [2,8–10], with the anodic electron and proton generating reactions catalyzed by living microorganisms as part of their metabolic processes. Anion and cation exchange membranes can be used in MFCs to transfer ions between the anode and cathode chambers [11–13].

Several factors affect on MFC performances, such as temperature, substrate concentration, electrode surface area and materials, internal and external impedances, pH and oxidation–reduction potentials in the cathode and anode chambers [3,14]. Recently, a number of investigators have conducted researches to enhance MFC performances [15]. One of the key factors affecting on MFC's

* 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).

0016-2361/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.fuel.2013.09.047

yield is the proton exchange membrane. Some studies on MFCs have developed cells to omit the membrane [16–20]. Zhang et al. have replaced the membrane with a glass fiber separator [21]. Liu et al. have removed the membrane in a two chambers of MFC [22] and produced bioelectricity using acetate as the electron donors. Removal of the membrane in a membrane less-MFC (ML-MFC) can cause high levels of oxygen intrusion from the aerobic cathode to the anaerobic anode. This phenomena decreases the ML-MFC columbic efficiency [2].

The main objective of this research was to omit membrane in dual chambers of MFC and generate bioelectricity in new configuration of ML-MFC. Also model the power generated by fabricated ML-MFC. For prediction of power artificial neural network was carried out. The used model had good ability for prediction of ML-MFC behavior.

2. Materials and methods

2.1. MFC fabrication and operation

A ML-MFC was fabricated from Plexiglas and consisted of two separate chambers. The empty bed volume of each chamber was 1000 cm^3 ($10 \times 10 \times 10$ cm). Each chamber has four baffles which facilitate mixing of the feed solution and increase the contact time between microorganism and electrode surface. The anodic and cathodic chambers were connected through a valve which could control flow between the chambers. Carbon paper electrodes coated with Pt were used as anode and cathode electrodes and were connected in an external circuit by copper wire. Experimental data were recorded using an online data logger (constructed by Biotechnology Group, Babol University of Technology, Iran). Oxygen was introduced to the cathode chamber by sparging with air. Fig. 1 shows a schematic diagram of the MFC with its auxiliary equipments. A characteristic of this design is that it effectively eliminates oxygen diffusion into anode chamber. The prepared substrate was transferred by a peristaltic pump (THOMAS, Germany) from the feed tank to the anode chamber and subsequently passed through the interconnecting tube and valve to the cathode chamber. ML-MFC was inoculated with anaerobic sludge collected from the dairy industry (Gella, Amol). The anodic media contained glucose, yeast extract, peptone and NH_4Cl: 5, 3, 3 and 0.3 g/l, respectively. Experiments were conducted at ambient temperature, 26–30 °C. The pH of the media was initially adjusted to 6.5 using phosphate buffer solution and the inoculums were introduced into the media at ambient temperature. The organisms were fully grown for the duration of 27 h. Substrate consumption was calculated on the basis of remaining sugars in the cultured media. Electron acceptor as an effective parameter on power generation at cathode compartment was analyzed. Optical density was measured using a spectrophotometer (UNICO, 2100 SERIES, USA) at wavelength of 540 nm and the calibration curve was prepared.

2.2. Chemical and analysis

All chemicals and reagents used for the experiments were analytical grades and supplied by Merck (Darmstadt, Germany). The pH meter (Model HANA 211, Romania) was employed to measure pH values of the aqueous phase. The surface images of the graphite plate electrode were obtained using a Scanning Electronic Microscope (SEM) (Supra 55vp-Zeiss, Germany). The images of the surface of the graphite electrode were taken before and after the experimental run. The sample specimen size for SEM analysis was 1 cm × 1 cm. SEM images were used to demonstrate the physical characteristics of the electrode surface and to examine the morphology of the bacteria on the anode surface.

2.3. Artificial neural network layers and validation

Neural network constitutes a branch of artificial intelligence which has recently undergone rapid evolution and progress [23]. Artificial neural network (ANN) utilizes interconnected mathematical nodes or neurons to form a network that can model complex functional relationship [24]. Its development started in the 1940s to help cognitive scientists understand the complexity of the nervous system. Basically, ANN is numerical structures inspired by the learning process in the human brain [25] and also can be considered as potential alternative for predicting the performance of waste treatment system [26,27]. Neural networks consist of three basic layers such as input, hidden and output layers. Some of ANNs are more popular such as multi-layer perceptron and radial basis function [28]. It has been showed that more complex nonlinear function can be modeled by a multilayer feed forward neural network [29]. In this study, a multilayer feed forward neural network was used which consists of an input, hidden and output layers. These used layers are shown in Fig. 2. That is explained the general topology of a multilayer feed forward neural network. Neurons in each layer connect together by a weight coefficient that called W_{ij} and W_{jk} [32]. There is a transfer function which change inputs

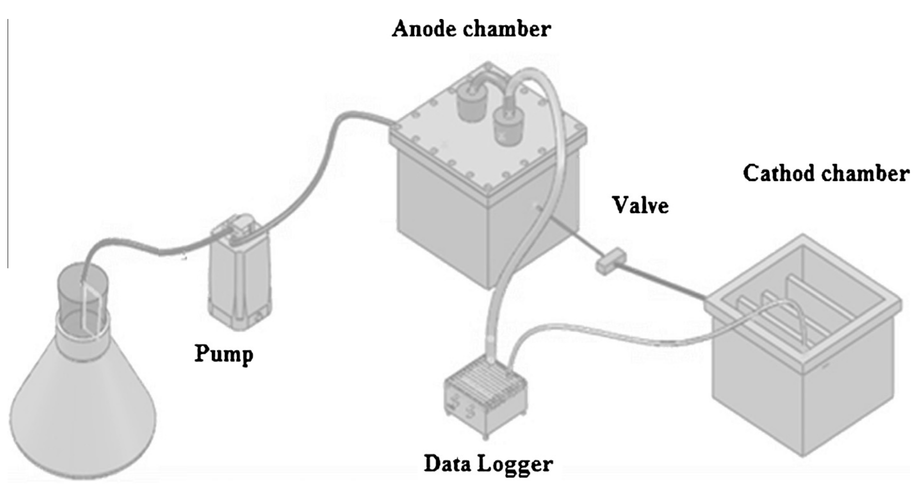

Fig. 1. Schematic diagram of ML-MFC with auxiliary equipment.