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Mathematical modeling of two-chamber batch microbial fuel cell with pure culture of *Shewanella*

Morteza Esfandyari, Mohmmad Ali Fanaei, Reza Gheshlaghi, Mahmood Akhavan Mahdavi*

Department of Chemical Engineering, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran

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ABSTRACT

Microbial fuel cell (MFC) is a bioreactor which converts the chemical energy of organic compounds of chemical bonds to the electrical energy by catalytic reactions. In the current study a dynamic model is proposed, based on the direct transfer of electron for a two-chamber batch MFC at constant temperature, in which, lactate is used as the substrate, *Shewanella* as the microbial culture, and air as the input to the cathode chamber. The proposed model has many parameters. Some of these parameters are selected from the literatures and the others are estimated based on the experimental data. The required experimental data are prepared from a two-chamber MFC with working volume of $135 \times 10^{-6}\,m^3$ for each chamber at two substrate concentrations of 5.0 and $7.5\,kg\,m^{-3}$. Three kinetic models known as Monod, Backman, and Tessier are used for describing the microbial specific growth rate. The results show that the better prediction of substrate concentration can be observed by using a Monod model ($R^2 > 0.97$). The predicted voltage and current of the MFC by the proposed model have good agreement with experimental data.

1. Introduction

The predicted voltage and current of the batch microbial fuel cell and compared with experimental data. MFC is one of the novel methods for the energy production, in which microorganisms generate electricity by conducting the oxidation–reduction reactions of a substrate. In such cells the electrochemical energy is directly converted to electrical energy (Allen and Bennetto, 1993). Although the application of MFCs was initially introduced in 1911 (Potter, 1911), little developments were made till recent decades (Oh et al., 2004; Xuan et al., 2009). Since in MFCs microorganisms act as electron donors, contrary to common fuel cells, they operate in moderate temperature and pressure conditions. One of the advantages of MFCs is their ability in conversion of the chemical energy from a biological environment to electrical current. Biocatalysts are applied for the conversion of chemical to electrical energy in the design of MFCs (Chaudhuri and Lovley, 2003; Rabaey and Verstraete, 2005). In some types of MFCs bacteria can be used as catalyst or microorganism (Chaudhuri and Lovley, 2003; Min et al., 2005).

Common MFCs usually have an anaerobic anode chamber and an aerobic cathode one, which are separated by a proton exchange membrane, the electrons and protons are produced in anode chamber during the oxidation of substrate by the microorganism (Du et al., 2011; Picioreanu et al., 2008, 2010b). Protons pass through the membrane to the cathode chamber, while electrons move from anode to cathode via an external circuit, therefore bioelectricity is generated in the circuit (Fig. 1). A final electron acceptor is required to complete this cycle in the cathode chamber. Commonly, oxygen has been used as the electron acceptor in the cathode chamber due to the high oxidation–reduction potential and low operating cost (Chou et al., 2013; Fitzgerald et al., 2013).

Many researchers investigated the effect of a variety of carbon sources on MFC performance, but few studies were thoroughly focused on the kinetic analysis of the type and concentrations of substrate (Jafary et al., 2013; Reimers et al., 2007; Sedaqatvand et al., 2011; Stein et al., 2011).

Abbreviations: DO, dissolved oxygen; OTR, oxygen transfer rate; OUR, oxygen uptake rate; MFC, microbial fuel cell; UV, ultraviolet; OD, optical density.

* *Corresponding author.*
E-mail address: Fanaei@um.ac.ir (M.A. Fanaei).

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