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Original Article

Effect of vitamins and cell constructions on the activity of microbial fuel cell battery

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ABSTRACT

Construction of efficient performance of microbial fuel cells (MFCs) requires certain practical considerations. In the single chamber microbial fuel cell, there is no border between the anode and the cathode, thus the diffusion of the dissolved oxygen has a contrary effect on the anodic respiration and this leads to the inhibition of the direct electron transfer from the biofilm to the anodic surface. Here, a fed-batch single chambered microbial fuel cells are constructed with different distances 3 and 6 cm (anode-cathode spacing), while keeping the working volume is constant. The performance of each MFC is individually evaluated under the effects of vitamins & minerals with acetate as a fed load. The maximum open circuit potential during testing the 3 and 6 cm microbial fuel cells is about 946 and 791 mV respectively. By decreasing the distance between the anode and the cathode from 6 to 3 cm, the power density is decreased from 108.3 mW m⁻² to 24.5 mW m⁻². Thus, the short distance in membrane-less MFC weakened the cathode and inhibited the anodic respiration which affects the overall performance of the MFC efficiency. The system is displayed a maximum potential of 564 and 791 mV in absence & presence of vitamins respectively. Eventually, the overall functions of the acetate single chamber microbial fuel cell can be improved by the addition of vitamins & minerals and increasing the distance between the cathode and the anode.

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1. Introduction

Clean renewable energy resources are important for solving the energy demand around the globe due to their sustainability and their distribution everywhere [1–3]. Among these common renewable energy sources is the Microbial fuel cell (MFC) – is recently explored. MFCs have the capability to use microbial communities as a catalyst and capture the electricity from a wide range of organic and inorganic substances (as microbial fuel or energy) through the biocatalytic activity of microbial aggregation [4–12]. In the microbial electrochemical systems, oxidation–reduction reactions are taking place through two consequent steps. Firstly, microbe-anode interaction is initiated to oxidize the organic substrate (electron donor) into free liberated protons and electrons [13]. Secondly, transfer of the produced electrons from the anode to the cathode via the external electrical circuit, and transferring the free protons into the cathode to form water and bioelectric

current through reduction of oxygen (electron acceptor) [14], as shown in Scheme 1.

Electron donor substrates are the main suppliers for electrons in the MFC [15], these substrates are ranging from a low molecular weight compounds to high molecular weight ones [16]. The produced power is depending on several factors as the availability of the organic loading rate, the capability of microorganisms loading rate, effect of electrode-spacing, and resistance value [17]. When the space between the two electrodes is reduced, the ohmic resistance is decreased as a direct result the protons have less distance to travel. Liu et al. demonstrated that, decreasing the spacing between the two electrodes from 4 to 2 cm led to reduce the ohmic resistance and increase of power output to a 67% [18]. While the other studies are proved the contradictory results. They have concluded that, when the two electrodes are located closely to each other, this lead to the increase of oxygen diffusion from the cathode to the anode. as a result the inhibition of the anaerobic respiration, is occurred with the promotion of the aerobic respiration, So power density is reduced [19–21]. The microbial fuel cell battery has been utilized in electricity generation [22,23], domestic and brewery wastewater treatment [24], biosensors [25,26], bioreme-

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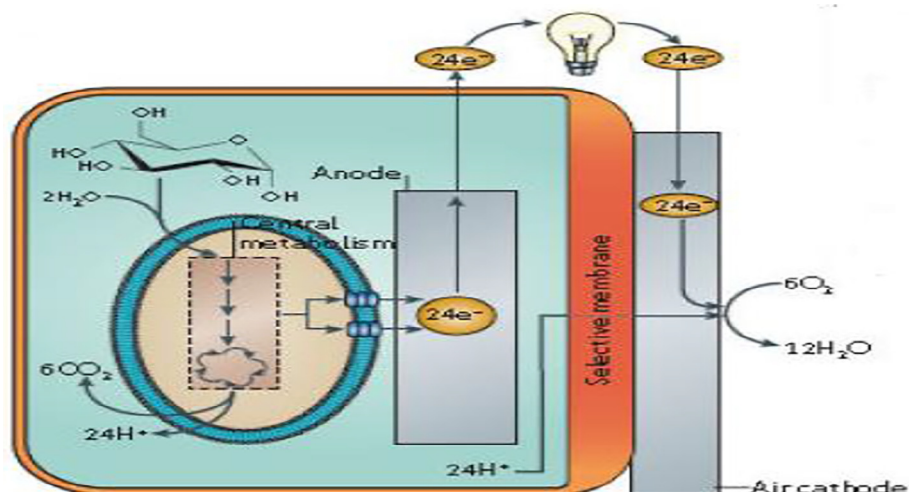
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Scheme 1. A mediator-less single chambered microbial fuel cell, the cathode is exposed to air on one side and to the anolyte containing the substrate on the other side [3].

diation [27–29], and as a remote power source [30]. Various attempts have been made to build larger MFCs or connect several MFCs in series (MFC stack operation) to increase the power output [31].

The bioelectrochemical characteristics of the activated sludge have been explored in literature, and promising results showed its good performance to be used in the operation and construction of the MFCs [2,13,22,23]. Thus in our study, attempts are developed to enhance the activity of Air-Cathode Single-Chamber Mediator-Less Microbial Fuel Cell (ACSCMMFC) by operating the parameters e.g. (minerals & vitamins load, resistance effect, and cell design of MFC-based on distance spacing systems).

2. Materials and methods

2.1. Microbial fuel cell constructions

Two transparent Perspex air-cathode single-chamber microbial fuel cells designs are constructed with an electrode active surface area of 25 cm². One with 50 ml total working volume (6 cm length and 4 cm diameter), the other with 20 ml volume (3 cm length and 4 cm diameter). It is composed of an anode and a cathode both are made from carbon paper, The cathode electrode is treated with Poly tetrafluoroethylene (PTFE) as diffusion layers on the air-exposed side [32]. The catalyst layer is prepared by mixing 0.3 mg cm⁻² of 30% Pt loading supported on carbon VulcanXC-72R and Nafion solution (5% Nafion solution from Aldrich) to form catalyst paste which stretched in the water facing side to reduce water loss and oxygen diffusion into the MFCs. The anode and the Pt- loaded side of the cathode are placed on opposite sides the solution. The cells are connected through an external circuit (open circuit, or 550 Ω). The performance of MFCs is evaluated with respect to power generation and substrate biodegradation.

2.2. Preparation of synthetic media solution

MFCs containers are supplied with aerobic activated sludge from the municipal wastewater treatment plant (**Benha municipal sanitation unit**) after filtration of the aerobic sludge to eliminate un-dissolved solid materials. The microbial fuel cells are fed with the synthetic wastewater with nourishment media. The nourishment media for 1 g of acetate is prepared using the following components (in grams per liter of deionized water): NaHCO₃, 2.5; NH₄Cl, 0.2; KH₂PO₄, 0.42; KCl, 0.33; NaCl, 0.3; K₂HPO₄, 1.26;

CaCl₂·2H₂O, 0.15; MgCl₂, 3.15; yeast extract 1. 10 ml of mineral media prepared as mentioned elsewhere [33]. The value of pH is adjusted to pH 7 using (HANNA pH211); nourishment media is refreshed when the cell voltage decreased below 50 mV. The inoculated MFCs are operated under fed- batch mode.

2.3. Microbial fuel cell operation

Two different MFCs are operated either after the inculcation of activated sludge microbial cells with the acetate based-nourishment media or after the inoculation of activated sludge microbial cells without nourishment media. The potential between the anode and the cathode is recorded every 5 min with a multi-meter and data acquisition system (Lab jack U6 – PRO). Polarization curves are obtained by varying external resistance (R_{ext}) from 100 to 125 kΩ, after a steady state of power and electricity generation for calculation of both maximum current and power density.

3. Results & discussion

3.1. Effect of minerals & vitamins

The performance of two membranes-less single chamber microbial fuel cells (MSCMFC) has been evaluated. The first cell is fed with 35 ml acetate media without vitamins & minerals. The other cell is inoculated with 35 ml acetate media containing minerals & vitamins and then, 15 ml of aerobic sludge is added to each set as illustrated in Fig. 1. In case of presence of mineral & vitamins, the cell voltage is gradually increased to a maximum voltage value (791 mV) along the degradation time then, is dropped to its lower value (50 mV) with depletion of media composition after successive cycles of replicates. While the cell voltage in absence of minerals & vitamins are increased to a voltage value (564 mV), then the voltage value is decreased to 50 mV. The open circuit cell potential is stabilized to approximately 564 mV & 791 mV in case of absence (red line) and presence (blue line) of minerals & vitamins respectively. This could be attributed to the requirements of living microbial cells to activate their enzymatic functions that rely on the metal salts as coenzymes or cofactors to enhance the bio-energy and biodegradation. On the other hand, minerals & vitamins are helping microorganisms in a biofilm formation, as has been shown previously by Beech et al. [34]. Some organisms can use the proteinaceous material as a nitrogen source; others use

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