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ELECTRICITY GENERATION USING DIFFERENT SUBSTRATES AND THEIR DIFFERENT CONCENTRATIONS IN MICROBIAL FUEL CELL

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Abstract. The need of electricity is getting increasing today due to industrial and technological requirements. It is also known that fossil oils are harmful to nature and getting exhausted. Due to these factors it is necessary to find both new and green electricity resources. Microbial fuel cell (MFC) as biofuel is one of them. It provides both nature-friendly electricity and treatment of wastewater. In this study, glucose and ethanol as substrates and their different concentrations were used both to treat wastewater and generate electricity. Multimeter was used to measure the voltage values of each substrate concentrations. It was proven that each substrate had different effect on microbial community. It was found that glucose was the most effective substrate for electricity generation in the concentration of 3000 mg/l total organic carbon (TOC).

Keywords: microbial fuel cells (MFCs), microbial community, total organic carbon (TOC), wastewater treatment, electricity generation.

AIMS AND BACKGROUND

In this study it was aimed to find the effect of different substrate sources and their concentrations on the generation of electricity in a microbial fuel cell (MFC). It is known that fossil fuels are the largest source of energy for the generation of electricity worldwide, as well as the largest worldwide anthropogenic sources of carbon dioxide release. But these kinds of energy sources cause not only global climate change (global warming), but also many serious environmental problems. It is obvious that fossil fuels are getting to exhaust all over the world with increasing technological developments and energy requirements together. Thus, scientists have focused on to find new renewable and nature-friendly energy sources to reduce utilising of fuel oils and to sustain energy needs[1]. Biofuels produced from

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biodegradable wastes are any gaseous or liquid fuels that can be used and stored as a fuel for several purposes in engines. Biofuels have almost zero emissions because carbon dioxide generated from them is fixed in the biomass[2].

It is not a new idea to generate energy using microorganisms. In 1911, Potter was the first scientist who studied electricity generation in MFC. He found that 'When organic materials are degraded by microorganisms, release electrical energy'[3]. After 55 years, Young et al.[4] constructed three different fuel cells after being realised the importance of electricity. At the end of 1980, Benetto[5] suggested that microorganisms have oxidation and reduction potential. Microbial fuel cell (MFC) is a reactor that provides to turn chemical energy existing in the organic materials to electricity energy. In order to generate more energy by using a MFC system, scientists have been gradually studying the reconstruction of reactors to identify microorganisms needed as a biocatalyst using different substrates. MFC systems have been reconstructed and designed by using different materials in order to obtain higher power. The most widely used MFC reactors up to now are one- and two-chambered reactors. Two-chambered MFC reactors are the most widely used design consisting of anode and cathode compartments separated by an ion exchange membrane (Fig. 1). In the anode chamber, electrochemically active anaerobic microorganisms take place, and these microorganisms release protons and electrons using organics and nutrients presented in the wastewater. Electrons are transferred throughout external resistant from anode electrode that is conductive to cathode electrode. Membrane allows to pass just cations due to its selectively permeable nature. In the cathode chamber, electrons transported through external resistance and protons passed through membrane in order to reduce O_2 to H_2O. Single-chambered MFC has only one compartment that contains both the anode and cathode. The anode is either placed away or close to the cathode separated by a proton exchange membrane.

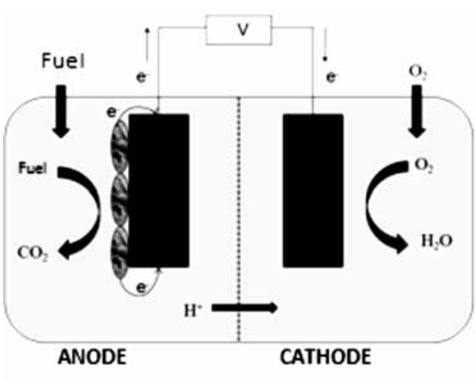

Fig. 1. Two-chamber MFC

In MFCs, bacteria are dominant species, and many of them have the ability to transfer their electrons to anode electrode. Bacteria used in MFC could be isolated from wastewater, sediments or earth. In MFCs, substrate is considered one of the most important factors to operate them properly because they are needed as a food and energy source for microorganisms[6]. Up to now, most of studies with MFCs have been used pure compounds such as glucose[7], acetate[8–12], ethanol[13–16] and cysteine as an amino acid[17] for electricity generation. In addition to these pure compounds, MFCs can generate electricity directly from various complex substrates such as domestic wastewater[18,19], ocean sediments[20] and various industrial wastewaters such as starch processing[21–23] and beer brewery[24].

At the anode compartment, fuel is given as substrate to anaerobic microorganisms, and microorganisms produce both electrons and protons while degrading it. Then generated electrons are transported to cathode compartment via their external wire. At the cathode compartment, oxygen molecules react with the protons permeating through the polymer electrolyte membrane and the electrons arriving through the external circuit to form water molecules.

EXPERIMENTAL

In this study, a two-chamber cubic MFC system was used (Fig. 2). Each compartment had 300 ml volume, and a cation exchange membrane (CEM) was used between anode and cathode parts in size of 10×10 cm. Anode and cathode chambers were connected to a multimeter (Keithley 2700 Data Acquisition) device to measure the produced voltage values in the system. Reactors were operated at room temperature, and fed a synthetic wastewater prepared with glucose and ethanol as different carbon sources. Each substrate was added in different concentrations range of 250–3000 ppm TOC. In order to avoid pH change in the reactors, a buffer solution was used in the compartments. At the beginning of the experiments, microbial biomass as inoculum was obtained from anaerobic sludge of a secondary clarifier taken from Wastewater Treatment Plants of Mersin. These bacteria were fixed on anode surface and acclimated for a month before the experiments. Water samples were withdrawn from anode compartment with two days period. Substrate consumption with time was measured by using Total Organic Carbon (TOC) analyser (Teledyne Tekmar, Torch, USA).

RESULTS AND DISCUSSION

The effect of different substrate sources and their concentrations on electricity generation in a MFC system was investigated in this study. According to experimental results, the organic matter (carbon) removal performance of system was directly related with their concentrations. The highest substrate concentration given to MFC reactors was removed more efficiently than the lowest one. TOC removal efficiencies for glucose were found as 48.5, 67.8, 77.1%, 84.5, and 90.4% for 250, 500, 1000, 2000 and 3000 ppm concentrations, respectively (Fig. 2). Almost all glucose concentrations were removed from the system at the 5th day.

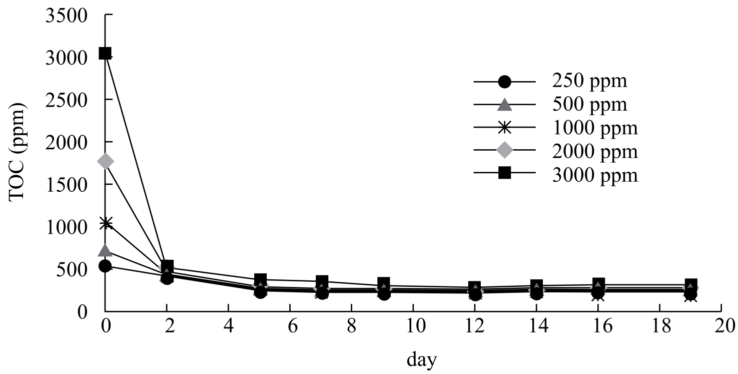

Fig. 2. TOC removal of MFC system fed with glucose

In order to determine ethanol removal efficiency of system, a second MFC reactor was operated under same experimental conditions, and was fed with ethanol as carbon source. According to the results, ethanol removal efficiencies were obtained as 44.6, 44.1, 50.2, 72.7 and 65.8% for same carbon concentrations, respectively (Fig. 3). Almost all ethanol concentrations were removed from the system at the 16th day. It was found that glucose consumption was faster than ethanol consumption by microorganisms in the MFC reactor.

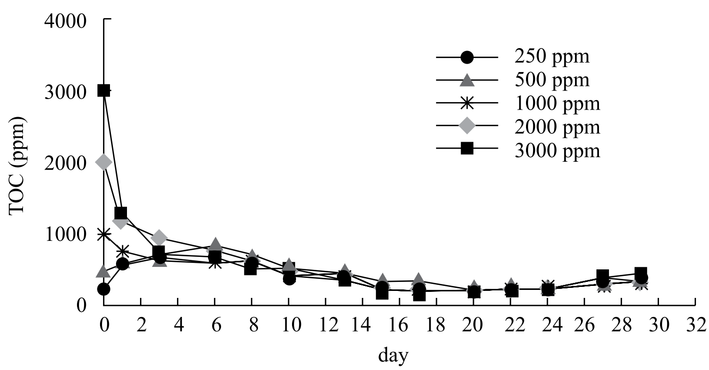

Fig. 3. TOC removal of MFC system fed with ethanol

Voltage results for the systems are shown in Figs 4 and 5. According to Fig. 4, voltage generation increased from the first day up to the 4th day for 250, 1000 and 2000 ppm glucose concentrations, and they decreased again on the 5th day with consumption of organic matter. This result was observed for 3000 ppm glucose concentration similarly. However, they did not change significantly with time after the 5th day. However, voltage generation for 500 ppm was obtained lower than higher glucose concentration of 1000 and 2000 ppm. Maximum electricity generation was obtained from glucose concentration of 1000 ppm, while the lowest values were obtained for the highest glucose concentration of 3000 ppm. For ethanol, voltage generation did not change with time for 2000 and 3000 ppm concentrations. However, it increased with time for 1000 ppm ethanol concentration and the highest voltage values were obtained for 500 and 1000 ppm ethanol concentrations. It can be said from the results that high ethanol concentration in the medium might cause toxic effects on microorganisms. When obtained voltage values were compared between two substrates, it can be seen that electricity generation was higher for glucose than ethanol. Zhang et al.[25] demonstrated that glucose generated more electricity compared to acetate and butyrate. Ethanol and methanol were used as carbon sources in another study, and researchers reported that electricity generation obtained from methanol was lower than from ethanol[26].

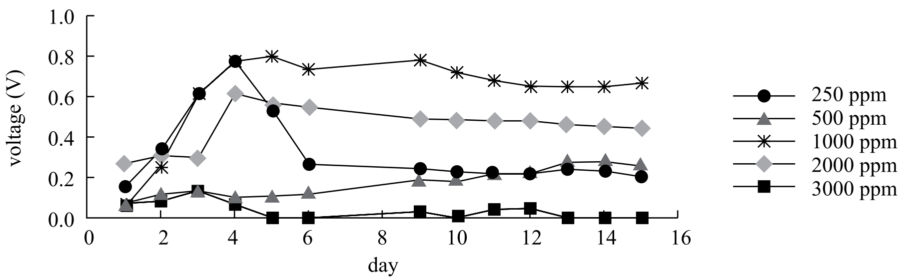

Fig. 4. Voltage generation in MFC reactor using glucose as carbon source

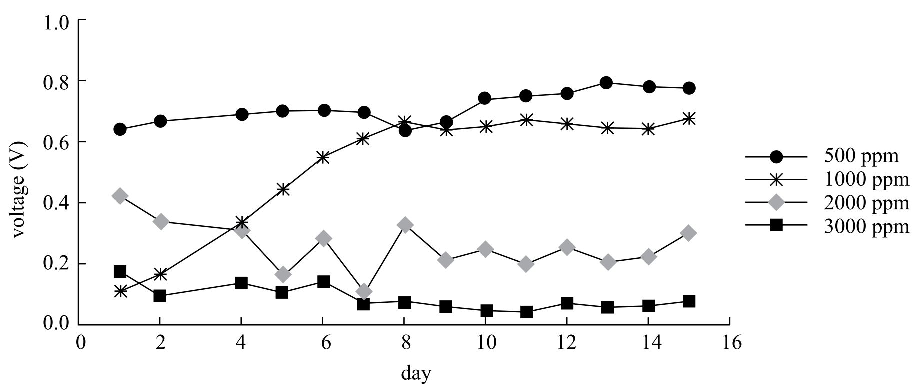

Fig. 5. Voltage generation in MFC reactor using ethanol as carbon source

CONCLUSIONS

In this study, carbon removal and voltage generation efficiency of a cubic MFC was studied by using glucose and ethanol as substrate sources. According to the obtained results, both of substrates were removed efficiently from the system. When comparing TOC consumption rates and obtained voltage values of systems, it was found that MFC reactor operating with glucose was more efficient than with ethanol in this respect. Almost all glucose concentrations were removed from the system at the 5th day, while all ethanol concentrations were removed after the 16th day. In terms of voltage values, the maximum electricity generation was obtained for glucose of 1000 ppm concentration, while it was determined for ethanol of 500 ppm concentration.

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