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The Usage of Molasses and Mediators in Microbial Fuel Cells

Merve ÖZTÜRK[1], Tuba ARTAN ONAT[2,*]

[1,2]Niğde Ömer Halisdemir University, Science and Arts Faculty, Biotechnology Department Niğde-Türkiye

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Abstract: Microbial Fuel Cells (MFCs) have an important role in today's research as clean energy sources. Microbial Fuel Cells enable the conversion of the chemical bond energy in organic materials to electrical energy by metabolic activities of microorganisms and, ensure solutions for wastewater treatment and electricity generation. The molasses has very high Chemical Oxygen Demand (COD) and low pH values and is located among 17 wastewater polluting the environment. In the study, molasses medium was used in the anode in dual chamber MFC, the effect of neutral red (NR) and methylene blue (MB) were investigated.as mediator on voltage. The bacterial community of MFC was fed with fresh molasses medium in fed-batch system and the COD value was calculated as 14 g/L. At the end of the 30-day incubation period, the voltage values were determined as 281 mV, 463 mV, 477 mV in the mediatorless molasses medium, with NR and MB respectively. Also, the decolorization of mediator dyes were determined for NR and MB. Decolorization yield of NR and COD removal rate were determined as %86 and %50 sequentially. In addition to this the decolorization yield and COD removal of MB were determined as %86 and %80 at 28 days incubation.

Key words: Microbial fuel cells, molasses, microbial community, bioelectricity,

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***Corresponding author:** tubaartan@ohu.edu.tr

INTRODUCTION

The usage of fossil fuels, which have supported industrialization and economic growth in all world economies as the main energy source, has led to the danger of extinction and increasing environmental concerns. The Microbial Fuel Cells (MFCs) is a new approach among renewable energy sources such as the wind and solar energies. Microbial fuel cells are systems that use bacterial metabolism as a catalyst to oxidize organic and inorganic materials and produce bioelectricity. Microbial fuel cells are suitable for direct electricity generation, anaerobic digestion, energy-saving, low sludge production, water treatment, energy and value added products - producing chemicals, low operating costs, resistance to environmental stress and will be the high-tech systems in the future. [Du *et al.*, 2007, Çatal *et al.*, 2008, Franks and Nevin, 2010, Singh *et al.*, 2010, Bakhshian *et al.*, 2011, Herrero-Hernandez *et al.*, 2013, Lin *et al.*, 2014, Gude, 2016, Trapero *et al.*, 2017].

The main aim of the MFCs is the usage of the electrons for bio electricity generation which is come out from the substrate oxidation. The electrons are transferred from the anode to the cathode by a mediator compound. Neutral red or methylene blue are compounds that could be added to anode chamber as mediators. In addition, the ferricyanide [$K_3Fe(CN)_6$] or permanganate could be used at cathode chamber as the last electron acceptor [Min *et al.*, 2005, Logan and Regan, 2006, Du *et al.*, 2007, Wang *et al.*, 2009, Rezaei *et al.*, 2009, Singh *et al.*, 2010, Pant *et al.*, 2010, Kiely *et al.*, 2011, Zhang *et al.*, 2011, Herrero-Hernandez *et al.*, 2013].

The main purpose of this study is to determine the effect of mediator compounds on voltage generation when molasses is used as the carbon source in the medium. For this reason, metyhlene blue and neutral red added to the molasses media and the voltage was followed with digital multimeter. Also Chemical Oxygen Demand (COD), mediator compound concentrations and decolorization of mediator compounds were determined as a function of incubation period.

MATERIAL AND METHODS

Anolyte (Molasses Medium) and Catholyte

In the anode chamber, molasses was used to provide bacterial growth. In the anode and cathode chamber, a 50 mM phosphate buffer solution was used, and 0.13 g/L KCl was added to buffer to increase the conductivity of the solution. 80 mL/L of molasses solution was added to 1.0 g/L $(NH4)_2SO_4$ and 0.5 g/L KH_2PO_4 50 mM 1 L phosphate buffer (Dönmez 2002). The pH

of the medium was settled at 7. In the cathode chamber, ferricyanide was used as the last electron acceptor to capture the electrons produced by the bacterial metabolism. 50 mM [$K_3Fe(CN)_6$] was added to 50 mM 1 L phosphate buffer solution [Zhang *et al.*, 2011, Logan *et al.*, 2006].

MFC Construction

In the study, glass MFC was used for voltage generation at total volume as 750 mL. 300 mL anode compartment was filled with molasses medium and connected to the cathode with 150 ml salt bridge that, was prepared with agar agar and saturated KCl solution. The anode compartment was fed with fresh molasses medium every 48 hours. The carbon electrodes were used for determining voltage generation in MFC which length was 10 cm and diameter was 0.8 cm. After the system was set up, the voltage difference due to the metabolic activities of the microbial community was monitored with a PeakTech 4390 multimeter at 20 minutes interval for all incubation period [Deval and Dikshit, 2013, Logan *et al.*, 2006].

Figure 1: Construction of microbial fuel cell

Mediator Compounds

Methylene Blue (MB) and Neutral Red (NR) were used to enhance electron transfer. The final concentration of the mediator compounds were settled as 200 mM for MM and 50 mM for NR in the MFC. The color ratio of the MM and NR were determined spectrophotometrically at 665 nm and 525 nm [Lin *et al.*, 2014].

In the study, pollution remediation was carried out with the follow-up of chemical oxygen demand (COD), and COD was measured according to the standard potassium dichromate technique [Zhang *et al.*, 2015].

RESULTS AND DISCUSSION

Molasses medium was prepared with 80 mL/L stock solution and inoculated with anaerobic sludge which was obtained from Akkaya Dam which was the wastewater discharge area. In Figure 2, the voltage values were shown at last ten days incubation period due to the voltage generation rate was constant at the MFC system. The maximum and minimum voltage values were determined as 375,4 mV and 268,1 mV at molasses medium without any mediator compound. These results were higher than literature value [Bakhshian et. al, 2011]. Therefore, MB increased the measurement of the voltage value and the maximum and minimum values were determined as 492,2 mV and 386.05 mV with 200 µM MB. These results were higher than another study [Mohan *et al.*, 2008]. Moreover, the maximum and minimum values with NR were determined as 573,6 mV and 371,2 mV and the results were very high than literature work [Lin *et al.*, 2014]. According to all these results, the microbial community in MFC was effective for usage at bioelectricity production.

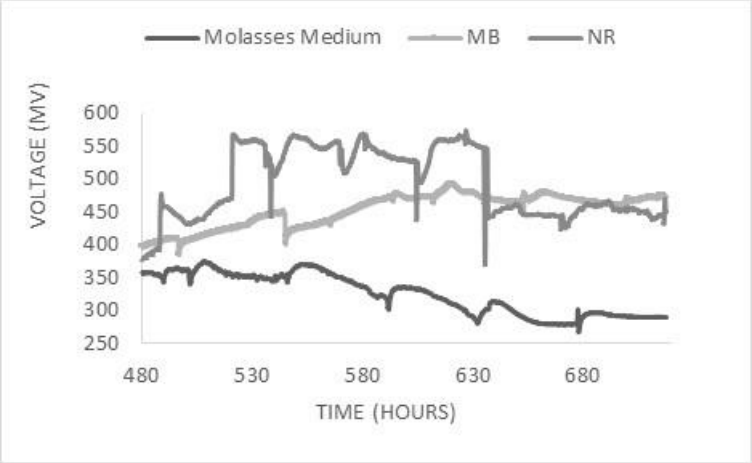

Figure 2: The voltage values in the 480-720 hours incubation period

The COD values of medium were determined in fed-batch MFC system at 2 day intervals for all the incubation period. This the microbial community was used the molasses and after adding the fresh medium hence, the COD values were stayed in equilibrium COD values that were determined approximately 16 g/L for NR and 14 g/L for MB and molasses medium (Figure 3). The COD values are similar to literature work (Satyawali and Balakrishnan, 2008)

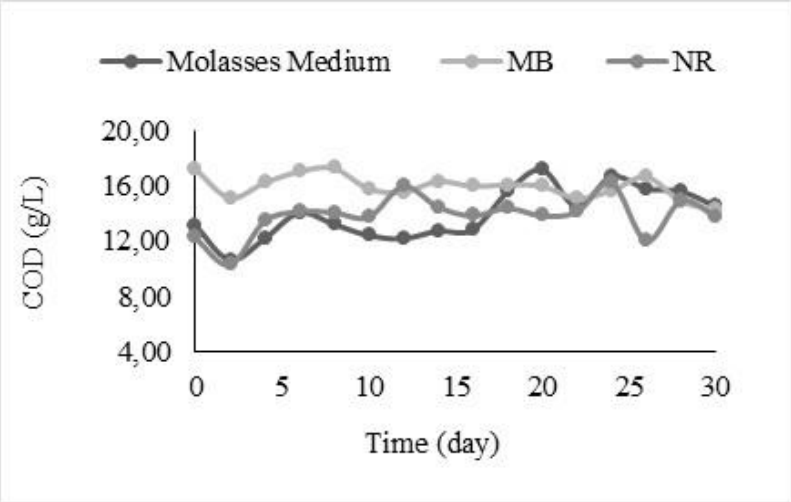

Figure 3: The COD values at fed-batch MFC

The mediator compunds added to medium at 50μM for NR and 200 μM for MB and mediator compound concentrations were stabilized as possible in fed-batch system (Figure 4).

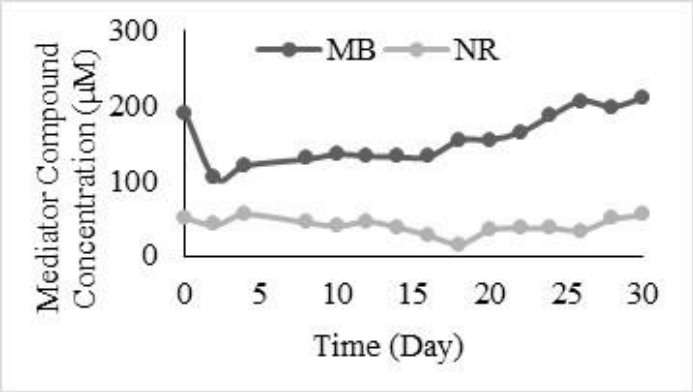

Figure 4: The mediator compound concentration at fed-batch MFC

It was determined that the MB and NR were removed by the microbial community during the incubation period, for this reason, color and COD removal experiments were performed on the batch system.

In Figure 5 the decolorization yield of MB and NR were shown. The NR added to molasses medium at 50 μM and 100 μM concentration and at 8 days the mediator decolorization were determined as 80%. The decolorization yield was stabilized at 8 days incubation period accordingly the experiment terminated at that point. The MB was added to molasses medium at 200 μM and 300 μM concentration. The decolorization yield of MB were determined as 90% at 16 days incubation period and the experiment was finished after 16 days incubation (Figure 5).

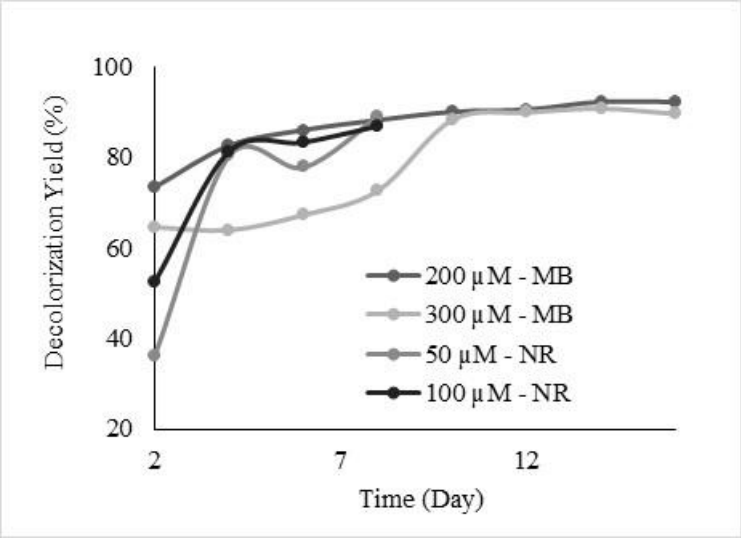

Figure 5: Decolorization yield of mediator compounds in molasses medium.

In Figure 6, the COD removal rates were given at molasses medium which were contained 50 and 100 µM NR, 200 and 300 µM MB concentration. The molasses was caused to higher COD values because of this the COD removal rate of MB were determined higher than NR due to incubation period length. The COD removal yields were determined as 51,46 for 50 µM NR and 44,41% for 100 µM NR, also 80,07% for 200 µM MB and 81,42 µM MB. These results showed that the microbial community obtained from Akkaya Dam could be used for voltage generation and COD and dye removal.

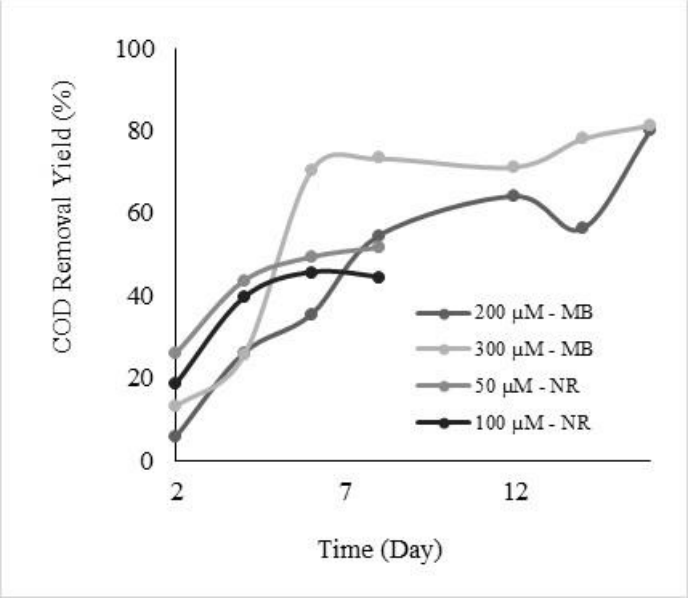

Figure 6: COD removal of molasses medium with mediator compounds

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