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Research Article

Microbial Fuel Cell for Conversion of Chemical Energy to Electrical Energy from Food Industry Wastewater

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Abstract

Microbial Fuel Cell (MFC) is a bio-electrochemical system that drives a current by using bacteria and mimicking bacterial interactions found in nature. This study was conducted to investigate the efficiency of MFC for electricity generation and removal of Chemical Oxygen Demand (COD). This research also study the effect of several parameters such as electrode sizes and type of microbial fuel cell on the performance of MFC. This study was carried out by using single and double chamber MFC. In effect, on electrode size, the 8×8 cm gives the highest maximum current generation which is 0.72 mA and highest COD removal efficiency of 62.96%. For effect of types MFC, single chamber microbial fuel cell gives the highest maximum current generation which is 0.78 mA and highest COD removal efficiency of 64.20%. This result shows that, MFC from food wastewater can convert chemical energy to electrical energy.

Key words: Chemical oxygen demand, MFC, electrode sizes, single chamber, double chamber

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Basically, this study is about treatment of industrial wastewater. The COD measures the amount of organic compounds in water. This study will help the wastewater treatment to be more efficient in reducing the percentage of COD. Its mean the lower the COD, the lesser the microorganism or bacteria. So, an idea of MFC which functioning exactly like electrolysis cells only that the difference is the sources used. The MFC is a unique device that utilizes the microorganism as catalyst for converting chemical energy directly into electricity, representing a promising technology for simultaneous energy production and wastewater treatment¹.

Therefore, to get higher amount of bacteria an organic waste type was chosen to be the source of wastewater. Usually, the different type of industry has different type of wastewater. The food industry has the highest value of organic in their organic wastewater type. The wastewater can be treated and also produced energy which will help meet the demand. The MFC can be done since an electrical action can induce a biological reaction, the converse in many cases is also true and in this way biological processes can be used to generate electricity. This would lead to the ability to utilize the materials. One of the earliest developments in this area was described by Michael Cresse Potter in 1911, when he placed a platinum electrode into cultures of yeast or *E. coli* and showed that a potential difference could be generated².

The MFC has wider applications including wastewater treatment, production of electricity, bioremediation and as environmental sensors³. The MFC has been used to treat various kinds of wastewater such as domestic sewage⁴, brewery^{5,6}, distillery⁷, sugar⁶, study and pulp⁸, rice mill⁹ and swine wastewater¹⁰. In this study, the treatment efficiency and electricity generation using single and double chambered MFC were experimented and comparisons were made between both MFC. Both types of MFC were operated at identical ambient environmental conditions.

This study was conducted to study about the effect of electrode size in single and double chamber towards electricity generation and percentage of COD removal.

MATERIALS AND METHODS

In this study only one type of industrial wastewater is used which is from food industrial factory located in Malacca. A few samples of wastewater have been taken from Farm Best's Berhad at Alor Gajah, Malacca and stored in a glass bottle. Carbon cloths were used as both anode and cathode.

This carbon cloth bought from HTH Engineering, Malacca. The size of the carbon cloths was divided into different sizes which were 6×6, 7×7 and 8×8 cm.

Two MFC were constructed, one was single chamber microbial fuel cell (SMFC) and the other one was double chamber microbial fuel cell (DMFC) (Fig. 1, 2). The reactors were constructed using non-reactive plastic containers which dimensions of 12.5×8×10 cm. The electrodes were connected by using copper wire. The salt bridge was made from a rope that was soaked in salt solution which is sodium chloride (NaCl). The electrodes were placed in the chambers, then were sealed and made airtight. Both reactors were checked for water leakage. The experiment was conducted in a controlled room temperature between 27 and 30°C. The experiment was conducted in batch mode and with a wastewater sample of 250 mL at each test. The untreated wastewater was used as a substrate and no any additional nutrients were given for microorganisms except the

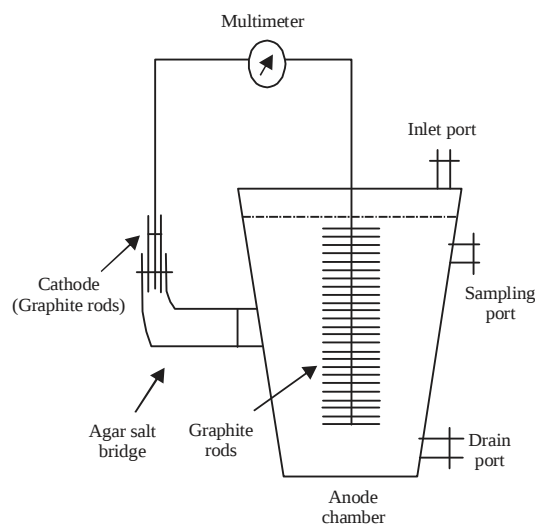


Fig. 1: A schematic diagram of SMFC

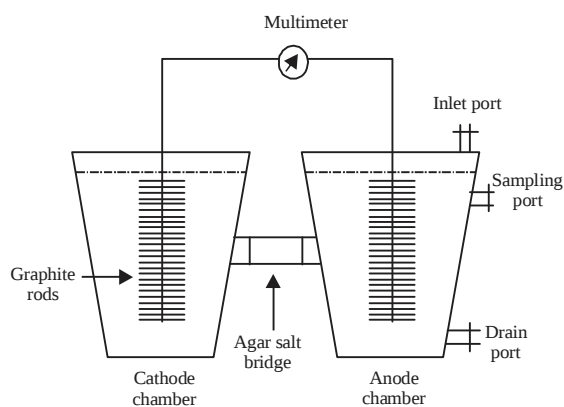


Fig. 2: A schematic diagram of DMFC

nutrients present in the wastewater. The anode chamber was filled with wastewater sample so that microorganisms in the wastewater could colonize the electrodes and produce electricity. The MFC was operated with a 100Ω external resistor.

RESULTS AND DISCUSSION

Based on preliminary results that shown in Fig. 3, size electrode of 8×8 cm produced maximum electricity generation. Figure 3 also shown that, the 8×8 cm carbon cloth give the highest current generation readings which are 0.45, 0.48, 0.53, 0.6, 0.72, 0.43 and 0.36 mA from 1-7 h. The 6×6 cm carbon cloth, give the lowest current generation readings which are 0.32, 0.34, 0.36, 0.51, 0.56, 0.30 and 0.26 mA from 1-7 h. At 1 h until 5 the current generation was slightly increased. At this phase, the bacteria on the anode chamber were decomposing the organic matter in the wastewater. This will free the H^+ ions and electrons from the bacteria to the anode. The electron will then flow from anode to cathode through a wire and generates current at the same time. At 5 h, the current generation was at its optimum point. During this phase, the bacteria were actively decomposing organic matter as food and later it start to deteriorate because the organic materials have been fully decomposed.

Figure 4 shows the 8×8 cm carbon cloth sizes also give the highest COD removal which is 62.96%. The COD decreased from $810-300 \text{ mg L}^{-1}$. The 6×6 cm carbon cloth size show the lowest COD removal which is 56.79%. The COD decreased from $810-350 \text{ mg L}^{-1}$. Based on this result, it can be said that the bigger the electrode surface area, more current can be generated because the bigger electrode surface area will let the bacteria to liberate electron transfer more rapidly¹¹. Besides that, the bigger the surface area, the higher the COD because the electron can be transferred more due to available surface area of anode. Thus the bacteria will decompose more of the organic matter which will reduce the COD. Based on preliminary results, the 8×8 cm carbon cloth was chosen to study the effect of electricity generation and COD removal in single and double chamber MFC.

Based on Fig. 5, single chamber microbial fuel cell gives the higher current generation compared to double chamber microbial fuel cell. At first 5 h for both microbial fuel cells, the current generation showed a gradual increase and then it start to decrease. The optimum current generation of single and double chamber microbial fuel cells was 0.78 and 0.72 mA, respectively. Single chamber microbial fuel cell has greater current generation because the cathode configuration is

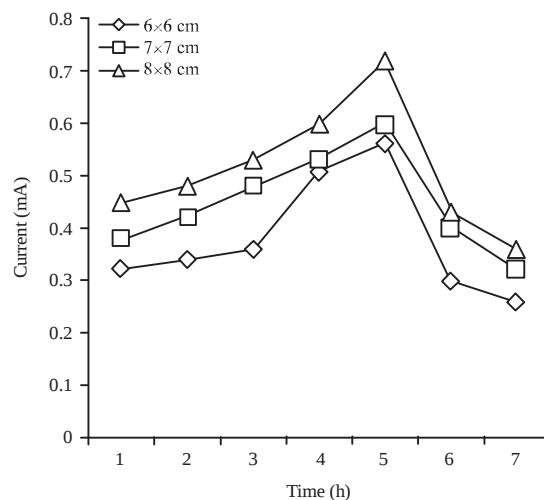


Fig. 3: Electricity generation performance of MFC for different electrode sizes

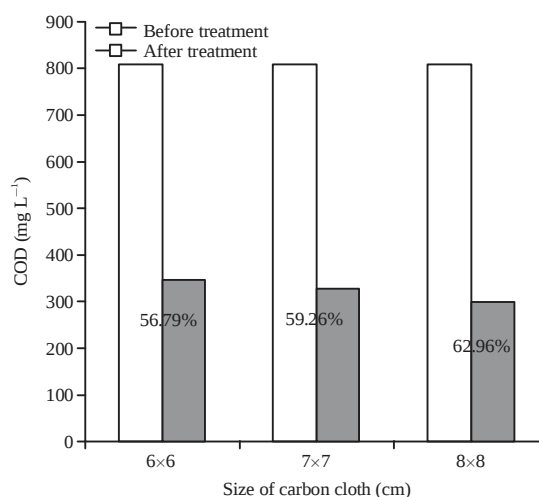


Fig. 4: COD removal efficiency for different electrode size

air-cathode different with double chamber microbial fuel cell that use cathode suspended in water. The abundant electron acceptor that is oxygen availability in the air is the reason for the higher current generation. The advantage of air-cathode microbial fuel cell is oxygen transfer to the cathode occurs directly from the air and thus oxygen does not have to be dissolved in water¹².

Figure 6 shows that the single chamber microbial fuel cell gives the highest COD removal which is 64.2%. The COD decreases from $810-290 \text{ mg L}^{-1}$. While double chamber microbial fuel cell shows the lowest COD removal which is 62.96%. Based on this result, the single chamber MFC has slightly higher COD removed than double chamber MFC because the oxygen availability was higher. Actually, the

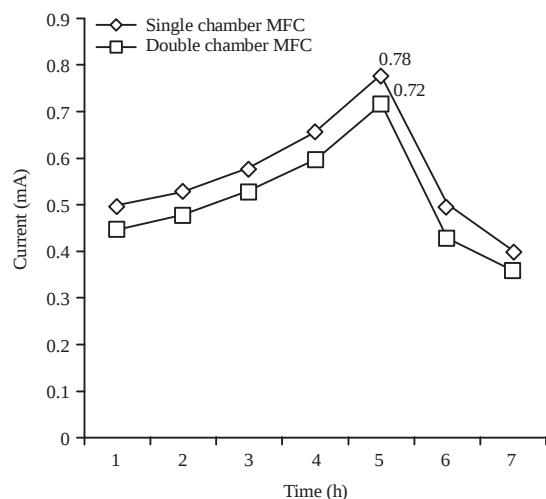


Fig. 5: Effect of different types of MFC towards electricity generation

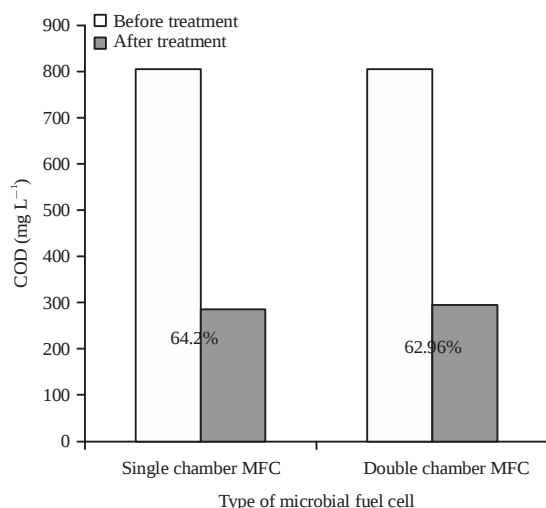


Fig. 6: COD removal efficiency for different type MFC

COD removal was depended on the anaerobic digestion in the anodic chamber. This is because when the anaerobic digestion occurred, the substrate will decompose and thus reduction of COD. That is why the COD removal was slightly difference at both tests. Besides that, the availability of an electron acceptor (i.e., oxygen) had a large impact on COD removal rates¹³.

CONCLUSION

Based on the experimental result of different size of electrode, highest current generation at optimum point has been achieved by 8×8 cm carbon cloth which is 0.72 mA. The lowest current generation at optimum point was from

6×6 cm carbon cloth which is 0.56 mA. As for COD removal, the 8×8 cm gives the highest percentage which is 62.96%. So, it can be concluded that the bigger the size of the electrode, the higher the electricity generated and COD removal efficiency. The highest current generation at optimum point was from single chamber microbial fuel cell which is 0.78 mA. The test in double chamber microbial fuel cell shows highest current generation which is 0.72 mA at the optimum point. The COD removal efficiency was higher in single chamber microbial fuel cell which is 64.2% compared to double chamber microbial fuel cell that is 62.96%. Thus, it can be said that single chamber MFC has better performance than double chamber MFC.

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