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Fast Biofilm Formation and Its Role on Power Generation in Palm Oil Mill Effluent Fed Microbial Fuel Cell

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Abstract. In the present study, fast formation and characterization of biofilm and its role on power generation in the microbial fuel cell (MFC) were investigated and the biofilm formation was also correlated with electrochemical behavior of the MFC. MFC was operated with palm oil mill effluent as substrate and carbon cloth as electrode. A biofilm comprising electrochemically active bacteria on the anode surface showed crucial effect to enhance the performance of the MFC. Infrared spectroscopy and thermogravimetric analysis confirmed the presence of biofilm and scanning electron microscopy examined a biofilm and microbial clumps on electrode surface. The current density was directly dependent on the biofilm growth and increased significantly during the initial growth. Electrochemical impedance spectroscopy was done to monitor the progress of the anode colonization by the microorganisms in the MFC. The findings of this study demonstrated that biofilm formation facilitated electron transport as well as decreased the charge transfer resistance of the anode and thus increased the power generation in the cell.

1 Introduction

Microbial fuel cell (MFC) is a bioelectrochemical energy system that opens a new window for eco friendly energy production to meet the growing demand and an economical pathway to a sustainable energy future. MFCs are capable of converting chemical energy available in organic substrates into electrical energy using bacteria as a biocatalyst to oxidize the biodegradable substrates [1]. The factors, such as substrate degradation, electrode material, type of microorganisms, rate of electron transfer from microorganisms to the anode, circuit resistance and proton mass transfer in the liquid mainly affect the MFC performance [2]. Different types of microorganisms have been studied in MFC such as *Clostridium butyricum* [3], *Escherichia coli* [4], *Geobacter sulfurreducens* [5], *Klebsiella pneumoniae* [6], *Pseudomonas aeruginosa* [7], *Rhodoferax ferrireducens* [8], *Shewanella oneidensis* [9], *Shewanella putrefaciens* [10] and so on. Eventhough, some pure cultures (e.g., *Geobacter metallireducens, Shewanella putrefaciens and Pseudomonas aeruginosa*) called electrogens are able to transfer electrons directly and produce current more or less equal to mixed cultures, it cannot utilize mixed or complex substrates. But, most of the industrial and domestic wastewater contains complex substrates and it makes pure culture not suitable for treating wastewater using MFC. Due to this reason, in most of the cases, anaerobic sludge [7] and activated sludge [11] obtained from wastewater treatment plant, have been used as inoclulum for the experiments. Therefore, these microorganisms should have grown and adapted to the condition of the wastewater.

Nevertheless, MFCs show real challenges to generate electric power for practical applications. Kim et al. [12] studied bacterial community structure (BCS), compartmentalization and activity in a MFC for a long period (18 months) and reported that BCS varied significantly in the anode biofilm. The research group as well showed that within 30 days of enrichment of microbial community was generated electricity (0.2 mA), using organic wastewater as the fuel [13]. Recently, Zhang, Zhu, Li, Liao and Ye [14] reported that biofilm is a crucial component in MFC for electrogenesis and it required only 14 days to be completely grown up at the anode compartment. Moreover, there are some barriers which limit the practical applications of MFCs, include ionic transfer restrictions, may increase the internal electrical resistance and oxygen transfer, therefore, decrease the overall cell performance [15]. Various attempts have been taken into account to overcome the electronic barrier. A number of electron-transfer mediators like biofilms have been used to facilitate electron transfer between an electrode and electrochemically active micro-organisms [16]. Anode potential is one of the most important factors at which the MFC is operated due to the control of theoretical energy gain for microorganisms [17]. In addition, the effect of external resistance applied to the electrical circuit also received wild attention and Zhang, Zhu, Li, Liao and Ye [14] reported that MFC performance increases with decreasing the applied external resistance [18] which may

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