MICROBIAL FUEL CELL: A GREEN TECHNOLOGY
SEL BAHAN BAKAR MIKROB: SATU TEKNOLOGI HIJAU

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Abstract

Microbial Fuel Cell (MFC) was developed which was able to generate bioenergy continuously while consuming wastewater containing organic matters. Even though the bioenergy generated is not as high as hydrogen fuel cell, the MFC demonstrated great potential in bio-treating wastewater while using it as fuel source. Thus far, the dual-ability of the MFC to generate bioenergy and bio-treating organic wastewater has been examined successfully using synthetic acetate and POME wastewaters.

Abstrak

Sel bahan bakar mikrob (MFC) yang mampu menghasilkan tenaga biologi secara berterusan daripada air buangan telah dibangunkan. Walaupun tenaga biologi yang dihasilkan oleh MFC adalah tidak setanding dengan sel bahan bakar hidrogen, namun MFC menunjukkan potensi yang tinggi untuk merawat air buangan yang juga digunakan sebagai sumber bahan bakar. Setakat ini, MFC yang dibangunkan telah diuji pada air buangan sintetik asetat serta POME dan telah menunjukkan penghasilan yang menggalakkan.

Keywords/Kata kunci: Microbial Fuel Cell, wastewater, bioenergy

INTRODUCTION

Microbial fuel cell (MFC) is one type of the biofuel cells which converts chemical energy to electrical energy. The recent advancement in the field of MFC provides promising technology not only to obtain energy but also to treat organic content wastewater at the same time. The system utilises electrochemically-active bacteria (EAB) as biocatalysts to oxidise organic contaminants in wastewater into electrical energy (Kim et al. 2007). This technology is generally regarded as a promising future technology for the production of green energy from organic materials in wastewater.

In this study, EAB was enriched from the palm oil mill effluent (POME). These bacteria show the ability to treat diluted POME wastewater, exhibiting the abilities to generate bioenergy while treating the wastewater. In addition, the bacterial community that resulted from the enrichment studies in the ML-MFCs was analysed using the bacterial genes of small ribosomal RNA subunit.

MATERIALS AND METHODS

MFC and operation

The MFCs were made of transparent polyacrylic plastic and consisting of two compartments, anode and cathode, as described previously (Jong et al. 2006). The MFCs were connected to an external resistance of 10 Ω during operation. Prior to startup, the anode compartment was fed continuously with POME collected from a palm oil processing mill in Dengkil, Selangor. The effluent was flushed through the anode compartment of the MFC system before being fed continuously with phosphate-buffered basal medium (PBBM) (Chang et al. 1999) incorporated with diluted POME wastewater (200 mg L^{-1}).

Analyses

The potential difference drop across an external 10 Ω resistor was measured every 5 min by a customized digital multimeter and connected to the signal conditioning system constructed using National Instruments (USA) parts. The signal was recorded on a personal computer with the LabView programming and the current was converted according to: Current (A) = Potential (V) / Resistance (Ohm), Power density (W/m^2) = Power (W) / Area of electrode (m^2). COD analysis of the anode effluent was performed using COD cell test kit (0-1,500 mg L^{-1} range, Merck KGaA, Germany). Polarisation curves of the MFC were obtained by varying the applied external resistance and recording the steady-state potential. All experiments were performed in triplicate and the mean values are presented.

Microbial diversity studies

Direct 16S rDNA sequence analyses were performed as described (Jong et al. 2006) from the bulk DNA extracted from anode electrode.

Scanning Electron Microscopy (SEM)

For scanning electron microscopic analysis, anode electrodes with biofilms were taken from the H-type MFC and were performed as described (Chung and Okabe, 2009). The coated samples were examined with a SEM (Leica Cambridge S360) at 3.5 kV.

RESULTS

Bioenergy generation

Electricity was generated continuously from diluted POME wastewater by ML-MFC in this study. The maximum power density (622 mW/m^2) was recorded as shown by the polarisation curve measured at various resistances. Voltage and maximum power generation as a function of current density obtained by varying the external load from 10 Ω to 10 kΩ (Figure 1). After two months of operation, the anode effluents showed a stable COD removal percentage of 23% and coulombic efficiency of 32%.

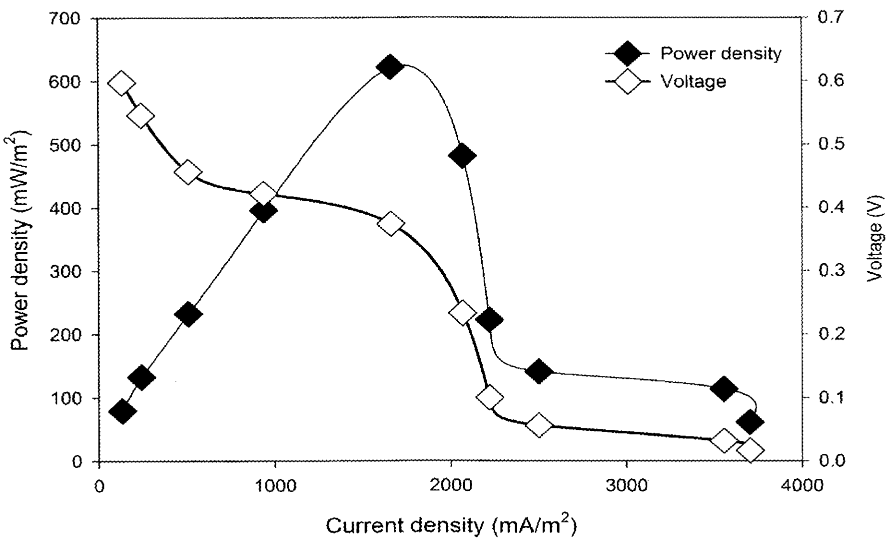

Figure 1. Polarisation curve measured at various resistances. Voltage and maximum power generation as a function of current density obtained by varying the external load from 10 Ω to 10 kΩ.

Table 1. Comparison of microbial diversity from various MFCs using EAB as biocatalyst

Operation mode	Fuel	MFC	Power density (mW/m^2)	Volumetric density (W/m^3)	Sources
Continuous	**POME**	**Double**	**622**	**55**	**Current study**
Batch	Organic WW	Double	8.3		Kim et al. 2004
Continuous	Fermented WW	Single		3	Nam et al. 2010
Batch	Starch processing WW	Single	239.4		Lu et al. 2009
Continuous	Acid-mine drainage	Double	290		Cheng et al. 2007
Continuous	Paper recycling WW	Single	672		Huang & Logan 2008
Continuous	Organic WW	Cassette	899	129	Shimoyama et al. 2008
Batch	Leachate	Double	3600		Rabaey et al. 2003

Microbial community analyses

Bulk DNA extracted from the graphite felt used as the MFC anode was further analyzed by 16S rDNA analyses. The 16S rDNA analyses showed that the microbial community was dominated by *Deltaproteobacteria* (88.52 %, Figure 2).

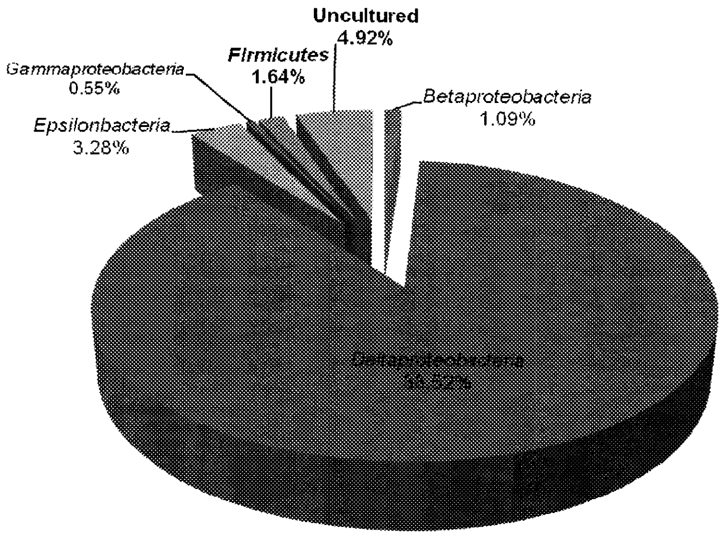

Figure 3. Distribution of POME ML-MFC anode bacterial populations as determined via ribosome shotgun sequencing consisting of 183 clones.

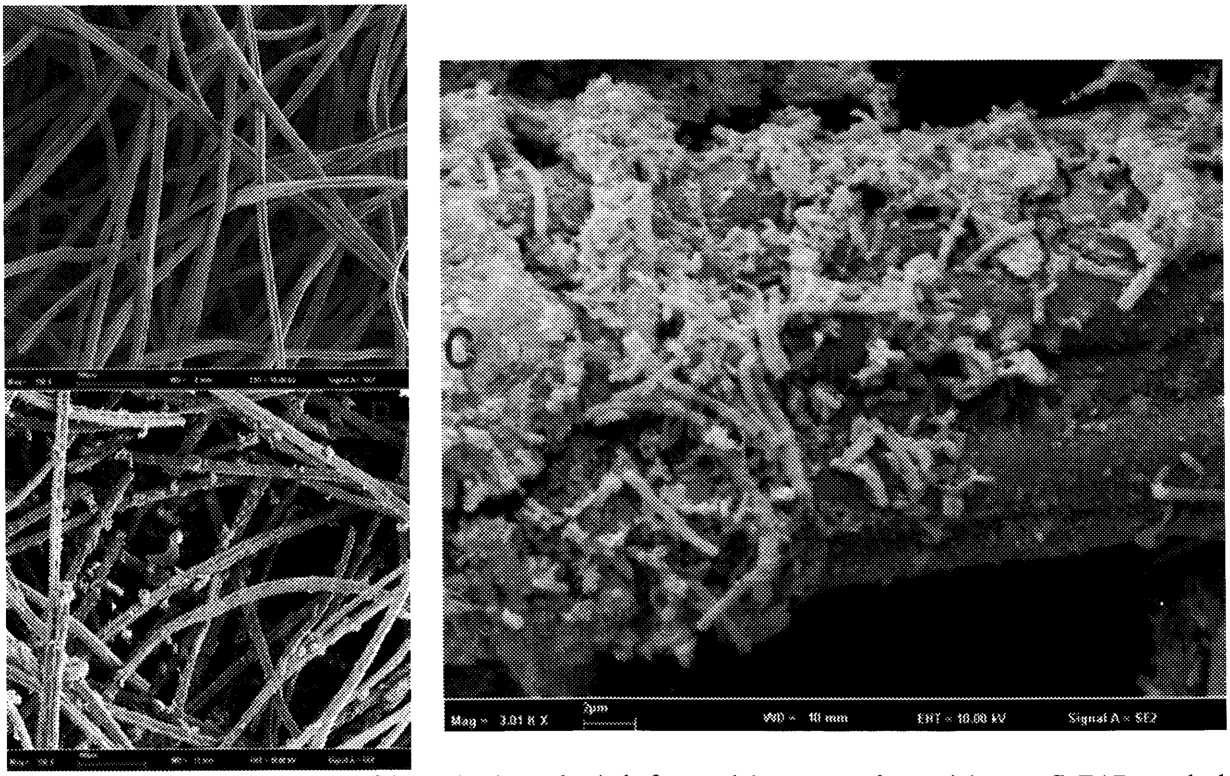

Figure 2. SEM images of graphite felt anode electrode. A, before enrichment; B, after enrichment; C, EAB attached on the surface of anode electrode.

DISCUSSION

Electricity was generated continuously from electrochemically-active bacteria either fed with artificial wastewater incorporated with acetate or diluted POME in this study. The maximum power density demonstrated in the present study was comparable to those previously reported (Kim et al. 2007). The 16S rDNA analysis showed that bacterial populations on the anode of MFC after 3 months of enrichment were different from those of POME which was used to inoculate the MFCs. The bacterial populations were less diverse after the enrichment than those of the inoculum by the PCR-DGGE gel analysis. The ultimate goal of the MFC is to remove organic pollutants in agricultural processing wastewater and convert them into electricity. We have shown that by using the MFC, at least 20 % of the organic content in the wastewater could be removed in a single flow-through process.

CONCLUSION

In conclusion, we have successfully enriched the electrochemically-active bacteria from POME in MFCs to generate electricity and treat both artificial and diluted POME wastewater simultaneously. Our study demonstrates the suitability of POME to be used as organic feedstock for electricity generation. Additionally, the reduction of COD in the wastewater by the MFC could be a promising and attractive option to the mill operator to fulfil the Department of Environment requirement on the COD contents of wastewater prior to being discharged to the environment. However, further investigation and search for lower costing materials and designs need to be explored to reduce the MFCs' cost and improve their performance for the oil palm industry in Malaysia. The improvements hopefully would lead to reduced cost of operating for wastewater treatment and maybe production of sufficient green energy to self-sustain the processing mill's activities.

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