TREATMENT AND GENERATION OF ELECTRICITY FROM PALM OIL MILL EFFLUENT USING LOCALLY ISOLATED ELECTROACTIVE MICROBES IN MICROBIAL FUEL CELL

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This thesis is dedicated to my beloved mother Fadumo Nour Abib, my wife Amal Mohamoud Jibril, my daughter Fadumo, my family members, my friends, in the Environmental Bioengineering Lab1, and my respective supervisor, Assoc. Prof. Dr. Zaharah Ibrahim for their endless support and encouragement.

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ABSTRACT

Palm oil industries are the largest agricultural based industries in Malaysia and in processing palm oil, high pollutant liquid waste known as palm oil mill effluent (POME) is being generated. Currently, treatment of POME to meet the standard discharge limit and generate environmentally friendly renewable energy has become an important issue. Therefore, this study was conducted to treat final discharge POME in microbial fuel cell (MFC) and generate electricity using electro-active bacteria from palm oil mill sludge (POMS). Double chamber MFC fabricated using polyacrylic sheets with a working volume of 1 L, proton exchange membrane (Nafion 115) and carbon electrodes connected to copper wires attached to a resistor of 10 kΩ were used. The anodic solution consisted of final discharge pond POME, overnight SRB1 inoculum (10% v/v) and phosphate buffer (pH 7) while the cathodic solution consisted of phosphate buffer (pH 7) and potassium hexacyanoferrate (III). The results showed 58% of COD removal and 60% of colour removal in 8 days. Simultaneously electricity generation was monitored and the maximum voltage, current density, power density and columbic efficiency recorded using a digital multimeter was 942 mV, 89.2 mA/m^2, 83.7 mW/m^2 and 54% respectively. The SRB1 bacterium that was used to treat the POME and produced electricity was later identified as *Pseudomonas aeruginosa strain NCIM 5223* using molecular techniques (16S rDNA analysis). In conclusion SRB1 was able to treat and generate electricity from final pond POME.

ABSTRAK

Industri minyak kelapa sawit adalah industri terbesar berasaskan pertanian di Malaysia dan dalam pemprosesan minyak kelapa sawit, sisa cecair pencemar yang tinggi dikenali sebagai Effluen Pemprosesan Kelapa Sawit (POME) turut dijana. Pada masa ini, rawatan POME untuk mematuhi had pelepasan standard dan menjana tenaga boleh diperbaharui yang mesra alam telah menjadi satu isu penting. Oleh itu, kajian ini telah dijalankan untuk merawat pelepasan POME akhir dalam Sel Fuel Mikrob (MFC) dan menjana tenaga elektrik menggunakan bakteria elektro-aktif dari sisa kelapa sawit enapcemar (POMS). Kebuk berkembar MFC distruktur menggunakan lapisan poliakrilik dengan jumlah kerja 1 L, membran pemindah elektron (Nafion 115) dan elektrod karbon disambungkan pada wayar tembaga yang dilampirkan pada perintang 10 kΩ. Cecair anodik terdiri dari kolam pelepasan POME akhir, inokulum semalaman SRB1 (10% v/v) dan penimbal fosfat (pH 7) manakala cecair katodik terdiri dari penimbal fosfat (pH 7) dan kalium heksasianoferat (III). Keputusan menunjukkan 58% penyingkiran COD dan 60% penyingkiran warna dalam tempoh 8 hari. Pada masa yang sama penjanaan elektrik telah dipantau dan voltan maksimum, ketumpatan arus, ketumpatan kuasa dan kecekapan kolumbik dirakamkan dengan menggunakan multimeter digital masing-masing adalah 942 mV, 89.2 mA/m^2, 83.7 mW/m^2 dan 54%. Bakteria SRB1 yang digunakan untuk merawat POME dan penghasilan tenaga elektrik kemudiannya dikenalpasti sebagai strain *Pseudomonas aeruginosa* NCIM 5223 menggunakan teknik molekul (analisis 16S rDNA). Kesimpulannya SRB1 dapat merawat dan menjana tenaga elektrik daripada kolam pelepasan POME akhir.

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LIST OF ABBREVIATIONS

ADMI	American Dye Manufacturing Unit
BOD	Biochemical Oxygen Demand
cm	Centimetre
C_E	Columbic efficiency
COD	Chemical oxygen demand
DNS	Dinitrosalicylic Acid
DO	Dissolved oxygen
et al	and others
g	gram
L	Litre
m	Millilitre
MFC	Microbial fuel cell
nm	Nanometer
PEM	Proton Exchange Membrane
pH	Hydrogen ion concentration
POME	Palm oil mill effluent
POMS	Palm oil mill sludge
rpm	Rotation per minute
TOC	Total Organic Carbon
TSS	Total suspended Solids
v/v	Volume over volume
°C	Degree Celsius
µL	Microliter

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Palm oil and soya beans are the most important vegetable oils in the world's oil and fats market (Igwe and Onyegbado, 2007). Palm Oil (*Elaeis guineensis)* is the most important species in *Elaeis* genus which belongs to the family of Palmae. Malaysia and Indonesia are the largest palm oil producing countries where they produce more than 90% of worlds palm oil export (Rupani *et al.*, 2010). Palm oil industries are the largest agro based industries in Malaysia and in 2008 more than 17,734,441 tonnes crude palm oil were produced (Wu *et al.*, 2010). However, production of this huge amount of crude palm oil lead to the generation of larger amounts of palm oil mill effluent (POME) and in 2008 more than 44 million tonnes of POME was generated in Malaysia (Wu *et al.*, 2010).

The extraction method of crude palm oil from the Fresh Fruit Bunches (FBB) adapted in Malaysia is wet palm oil milling process (Ibrahim *et al.*, 2012). Wet milling process consists of several stages including sterilisation, stripping, digesting, and oil extraction. Extraction of the crude oil uses large volume of water generating huge quantities of POME wastewater. Raw POME is an acidic, brownish, colloidal suspension, and non-toxic if chemical is not added during the process, containing high

environmental pollutant elements including; COD, BOD, total solids, suspended solids, oil and grease (Ahmad *et al.*, 2003).

Discharging POME without proper treatments cause problems to the environment (Wood *et al.*, 1979). For this reason, Malaysian government has set Environmental Quality Act 2009 which defines the standard discharge limit of effluent. Biological treatment is the common treatment method of POME adopted in Malaysia though other treatments such as; physicochemical and membrane filtration is considered. Improving treatment methods of POME and generating environmental friendly, renewable energy can contribute to environmental cleaning.

Studies done in the last 3 decades shown that microbial fuel cell (MFC) can generate green electricity. MFC is a reactor that converts biochemical energy into electrical energy using the catalytic action of the microbes. Microbial substrate reduction-oxidation (redox) reaction is the basic principles of the MFC. There are many types of MFC including mediator MFC, mediatorless MFC, mediator and membrane less MFC, up flow MFC, and stacked MFC. Designing MFC into single or double chamber is very commonly used.

MFC consists of two compartments anodic and cathodic compartment separated by proton exchange membrane (PEM) or salt bridge each filled with anolytes and catholytes. Carbon graphite is commonly used as electrodes in MFC because of its conductivity and low cost. Microbial metabolic reactions on substrates generate electrons and as POME contains many organic molecules it has potential to generate more electrons.

1.2 Problem statement

Palm oil plantation and industries are increasing rapidly in Malaysia and the neighbouring countries. These results the increase in production of POME. Palm oil industry is recognized as the largest river polluting agro-industries throughout the country. For that reason, the Malaysian government had set standard discharge rules and regulation for the polluting parameters. In order to meet the standard discharge limits palm oil industries treat POME in many ways including conventional treatment.

Consumption of energy is dramatically increasing due to demand of the transportation sector, electrically operating products used and industries. Microbial fuel cell is a device that can convert the biochemical energy into electrical energy using the catalytic action of the microbes (Kim *et al.*, 2002). Organic wastes like POME are rich in biochemical energy that indigenous microbes are able to harvest (Heck *et al.*, 2002). Previous studies have reported the treatment of POME using both physical and biological method, and in addition, generation of electricity from wastewaters. However, this study was carried out to treat and generate electricity simultaneously from POME using electroactive microbes from palm oil mill sludge (POMS) in MFC.

1.3 Objectives of the study

1. To isolate electroactive microorganisms from palm oil mill sludge (POMS)
2. To treat POME wastewater using selected electroactive microbes
3. To generate green electricity from treatment of POME

1.4 Scope of study

In this study, isolation and identification of elecetroactive bacteria from palm oil mill sludge (POMS) using molecular techniques (16S rDNA) was carried. Bacteria obtained were used to treat and generate electricity from POME using MFC. Colour and COD removal were focused to treat from the final discharge pond. Subsequently, generation of electricity was measured.

1.5 Significant of the study

Previous studies showed that POME contributes pollution of the watercourse. Discharging POME into the rivers can cause destruction of aquatic life. Treating POME becomes an important public concern not only to save the environment but also human health. Furthermore, electricity consumption rate increases due high production and usage of electronics. Energy generated from fossil fuels contributes to climatic change and global warming and are not renewable. Thus, immediate action needs to maximize environmental cleaning process and minimize global warming by replacing the use of fossil fuels with renewable, environmentally friendly green electricity using MFC.

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