Faculty of Engineering

THE EFFECT OF NUTRIENT IN ANODIC CHAMBER TO THE PERFORMANCE OF MICROBIAL FUEL CELL

Nashley Ursula Mundi Anak Ujai

Bachelor of Engineering

Electrical and Electronics Engineering with Honours

2022

UNIVERSITI MALAYSIA SARAWAK

Grade: ____________

Please tick (√)

Final Year Project Report	✓
Masters	
PhD	

DECLARATION OF ORIGINAL WORK

This declaration is made on the 27th day of June 2022.

Student's Declaration:

I **NASHLEY URSULA MUNDI ANAK UJAI (66908), DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING, FACULTY OF ENGINEERING** hereby declare that the work entitled **THE EFFECT OF NUTRIENT IN ANODIC CHAMBER TO THE PERFORMANCE OF MICROBIAL FUEL CELL** is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person.

27TH JUNE 2022
Date submitted

NASHLEY URSULA MUNDI ANAK UJAI (66908)

Supervisor's Declaration:

I **PROF. MADYA. TS. DR SITI KUDNIE BT SAHARI** hereby certifies that the work entitled **THE EFFECT OF NUTRIENT IN ANODIC CHAMBER TO THE PERFORMANCE OF MICROBIAL FUEL CELL** was prepared by the above named student, and was submitted to the "FACULTY" as a * partial/full fulfillment for the conferment of **BACHELOR OF ENGINEERING, ELECTRICAL AND ELECTRONICS ENGINEERING WITH HONOURS**, and the aforementioned work, to the best of my knowledge, is the said student's work.

Received for examination by: ____________________
(PROF. MADYA. TS. DR SITI KUDNIE BT SAHARI)

Date: 27TH JUNE 2022

I declare that Project/Thesis is classified as (Please tick (√)):

☐ **CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1972)*****
☐ **RESTRICTED** (Contains restricted information as specified by the organisation where research was done)*****
☑ **OPEN ACCESS**

Validation of Project/Thesis

I therefore duly affirm with free consent and willingly declare that this said Project/Thesis shall be placed officially in the Centre for Academic Information Services with the abiding interest and rights as follows:

- This Project/Thesis is the sole legal property of Universiti Malaysia Sarawak (UNIMAS).
- The Centre for Academic Information Services has the lawful right to make copies for the purpose of academic and research only and not for other purpose.
- The Centre for Academic Information Services has the lawful right to digitalise the content for the Local Content Database.
- The Centre for Academic Information Services has the lawful right to make copies of the Project/Thesis for academic exchange between Higher Learning Institute.
- No dispute or any claim shall arise from the student itself neither third party on this Project/Thesis once it becomes the sole property of UNIMAS.
- This Project/Thesis or any material, data and information related to it shall not be distributed, published or disclosed to any party by the student except with UNIMAS permission.

Student signature ____________________ Supervisor signature: ________________
(27th June 2022) (27th June 2022)

Current Address:
<u>NO. 7 LOT 224, TAMAN TIAN LIN, BUKIT SIBAU, 95700 BETONG, SARAWAK.</u>

Notes: ***** If the Project/Thesis is **CONFIDENTIAL** or **RESTRICTED**, please attach together as annexure a letter from the organisation with the period and reasons of confidentiality and restriction.

[The instrument is duly prepared by The Centre for Academic Information Services]

THE EFFECT OF NUTRIENT IN ANODIC CHAMBER TO THE PERFORMANCE OF MICROBIAL FUEL CELL

NASHLEY URSULA MUNDI ANAK UJAI

A dissertation submitted in partial fulfilment
of the requirement for the degree of
Bachelor of Engineering
Electrical and Electronics Engineering with Honours

Faculty of Engineering

Universiti Malaysia Sarawak

2022

Especially dedicated to

my lovely father Ujai Sambau and my beloved mother Nana Linggang,

my dearest pet dogs Juju, Joji and Lola,

family and friends

for their unconditional love and support.

ACKNOWLEDGEMENT

With this opportunity, I would like to express my greatest gratitude and appreciation especially to my family who is riding along and never fails to continuously encourage me throughout this journey. For the endless motivation and support both emotionally and financially that was given to me to pursue this study.

Deepest appreciation goes to my dedicated supervisor, Prof. Madya. Ts. Dr Siti Kudnie Sahari for her guidance, advices, words of motivations, patience, care and continuous support throughout this project. For her time and her careful attention to the details of the project, which play a major role in accomplishing this project.

Not to forget, I would like to thank especially the lecturers of UNIMAS and those who directly or indirectly helped me throughout this project.

ABSTRACT

Microbial fuel cell (MFC) is a device used to generate bioelectricity in which it converts chemical energy into electrical energy with the microorganism found in the system act as the biocatalysts. In this project, the objectives are aimed to interpret on the performance of the single-chamber microbial fuel cell with the influence of nutrients from the bamboo leaves, rice husk and coconut waste that are being oxidized by microorganisms in the anodic chamber as well as to improve the generation of electricity through microbial fuel cell by adding new nutrient contained in the organic wastes (bamboo leaves, rice husk and coconut waste) with adding potential catalyst (organic compost). There were four different experiments conducted in this project in order to understand the influence of nutrient to the performance of microbial fuel cell. In these experiments, the anode materials used are bamboo leaves, rice husk and coconut waste, in which organic compost was added to all of these mixing samples later on. The ratio between the organic wastes and organic compost were adjusted throughout conducting the experiments. The other experiment in this project is that a set of three single-chamber microbial fuel cells were connected in series and parallel to evaluate on the improvement of the bioelectricity generated. Day 5 of conducting the experiment recorded the highest current density and power density generated which are at 190.85mA/m^2 and 788.58μW/m^2 respectively. The single-chamber microbial fuel cells that were connected in parallel connection showed a relatively higher current density and power density at 21.47mA/m^2 and 55.98μW/m^2 respectively, compared to when the single-chamber microbial fuel cells were connected in series which its current density is 19.38mA/m^2 with the power density at 48.75μW/m^2.

ABSTRAK

Microbial fuel cell (MFC) merupakan satu peranti yang digunakan untuk menjana bioelektrik, dimana ia dihasilkan dari penukaran tenaga kimia kepada tenaga elektrik oleh biomangkin iaitu mikroorganisma yang didapati di dalam sistem tersebut. Objektif projek ini adalah untuk memahami bagaimana nutrisi yang terdapat daripada daun buluh, hampas beras dan hampas kelapa yang dioksidasikan oleh mikroorganisma dapat mempengaruhi sistem *single-chamber microbial fuel cell* and juga bagaimana kompos organik dapat menambah baik sistem *single-chamber microbial fuel cell* bilamana ianya ditambahkan dalam sisa organik (daun buluh, hampas beras dan hampas kelapa) yang digunakan dalam sistem tersebut. Terdapat empat eksperimen yang akan dijalakan dalam projek ini. Dalam eksperimen ini, daun buluh, hampas beras dan hampas kelapa akan digunakan sebagai bahan anod dan kemudiannya kompos organik akan ditambahkan ke dalam kedua-dua sisa organik ini. Nisbah di antara sisa organic dan kompos organik akan diubah-ubah semasa menjalankan eksperimen ini. Manakala, eksperimen yang terakhir adalah tiga set *single-chamber microbial fuel cells* akan disusun dalam litar sesiri dan litar selari bagi menilai dengan lebih mendalam bagaimana ianya dapat meningkatkan penjanaan bioelektrik di dalam *single-chamber microbial fuel cells*. Didapati *current density* dan *power density* yang tertinggi iaitu 190.85mA/m^2 dan 788.58µW/m^2 telah direkodkan pada hari ke-lima dalam menjalankan eksperimen ini. *Single-chamber microbial fuel cells* yang disusun dalam litar selari merekodkan *current density* dan *power density* yang lebih tinggi iaitu 21.47mA/m^2 dan 55.98µW/m^2 berbanding apabila *single-chamber microbial fuel cells* tersebut disusun dalam litar sesiri dimana *current density* yang direkodkan adalah 19.38mA/m^2 dengan *power density* pada 48.75µW/m^2.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF GRAPHS

LIST OF FIGURES

LIST OF ABBREVIATIONS

MFC	Microbial Fuel Cell
FYP	Final Year Project
PEM	Proton Exchange Membrane
BOD	Biochemical Oxygen Demand
OCV	Open-Circuit Voltage
MMFC	Mud Microbial Fuel Cell
CEM	Cation Exchange Membrane
COD	Chemical Oxygen Demand
OLR	Organic Loading Rate
BCT	Bamboo Charcoal (BCT)
GT	Graphite Tube
TMFC	Terrestrial Microbial Fuel Cell

CHAPTER 1

INTRODUCTION

1.1 Research Overview

This chapter presents an overview of the research background which includes the energy needs together with the current power generation method used worldwide, the discovery of bio-electricity which introduce a little bit on microbial fuel cell (MFC) as well as the use of bamboo in Sarawak. In general, these topics are essential to outline the complete introduction to this final year project (FYP) title.

1.2 Energy Needs and Current Power Generation Method

As of 2019, it was believed that in the next 30 years the world's population is expected to grow from 7.7 billion to 9.7 billion in 2050, which as reported by the United Nations, escalated by 2 billion persons [1]. By logic, the energy demand will increase with the growing of the world's population size. It was claimed that the energy needs in Malaysia will increase by 5242MW in 19 years, which is 18,808MW in 2020 to 24,050MW in 2039 [2].

At some point, the current power generation method such as the fossil fuels would not be able to keep up with the global energy demand and eventually unable to generate enough electricity worldwide. To explain further, fossil fuels which are made up of decomposing plants and animals that were buried by layers of rock from over million years ago [3] are a non-renewable energy resources which comply of coal, oil and natural gas [4]. These non-renewable energy resources will run out sometimes in the future due to the constant burning of fossil fuels to generate electricity which is why finding a renewable alternative to produce electricity to consumers everywhere is fundamental.

One of the most famous renewable resources used globally nowadays is hydropower. Even though it is true that Malaysia uses fossil fuels but other power generation method used in this country is hydropower. As a matter of fact, the biggest hydropower plant in the country is the Bakun hydroelectric power plant, located in Sarawak itself. It is said that this hydropower plant will be able to generate up to 2400MW of electricity [5].

Be that as it may, both fossil fuels and hydropower however have its own downsides. Besides being non-renewable, fossil fuels are one of the factors contributing to global warming. That is to say, burning fossil fuels will emit large quantities of CO_2 in the air which in the long run leads to climate change due to the heat trap from the emission of carbon [6]. According to CNN in February 2021 [7], over 8 million people died globally every year as the consequences of breathing polluted air from the burning of fossil fuels which contain particles such as the greenhouse gasses. Hydropower on the on the other hand may be one of the biggest renewable resources, however it can cause social threats and damage to wildlife habitat and harmed the water quality near the dam area. This is because the hydroelectricity may cause changes in reservoir and the water quality of the stream. The water temperature and the river's flow may change which will later bring harm to the native plants and animals near the area [8].

1.3 Discovery of Bioelectricity

Back in 1790, an Italian physician, physicist, biologist and philosopher, Luigi Galvani first stumble upon a bioelectricity phenomenon. MFC however, was actually first discovered somewhere around the beginning of the 20th century. In 1931, Barnett Cohen bring to light on this discovery of renewable resource and was able to build a half fuel cells that were able to generate up to 35V and 2mA with the MFCs connected in series [9].

To explain in detail, MFC is a device used for bio-electrochemical process which ideally implement to generate bioelectricity through the electrons derived from the biochemical reactions catalysed by bacteria which to be specific, the anaerobic oxidation of substrates [10]. For the most part, MFC is incorporated of proton exchange membrane (PEM), that is to separate the two main parts of MFC which are the anode chamber and cathode chamber. The idea is that, electricity will be produced for when protons and electrons are moved from anode to cathode chamber through PEM and an external circuit respectively. The protons and electrons existed in the MFC as it was released during the anaerobic oxidation of organic substances in the anode compartment [11]. Typically, the organic substances are glucose, ethanol, acetate and lactate.

Aside from producing bio-electricity, MFC is also commonly used for wastewater treatment, determining biochemical oxygen demand (BOD) levels as well as for biosensors. To emphasize, bioenergy that is produced from the anaerobic oxidation of organic substrates in MFC is capable to replace lithium batteries and act as a self-renewable long-standing power supply for both biosensors and remote monitoring sensors [12]. To compare it with the other power generation methods mentioned before, MFC is eco-friendly and produce low carbon emission. It is an efficient conversion of substates to electricity. For instance, organic waste such as food waste or water waste can be used to produce electricity through MFC. Since MFC operates from the conversion of biodegradable substances into simpler substances to generate bio-electricity, thus water waste by the same token, can be used as the alternative organic substrate mentioned here. In the same time, this will help to reuse this wastewater instead of chemically treating it that in the end might negatively affect the environment and thus, indirectly reduce the amount of waste that is usually thrown away in a daily basis. It is clear that, generating bioenergy from MFC helps in reducing carbon footprint as well as the environmental pollution [12] in a sustainable and environmentally-friendly way.

1.4 Bamboo in Sarawak

Bamboo or scientifically known as *Bambusoideae* is one of the most abundant native plants in Asia. In Malaysia alone, there are at least 70 species of bamboo founded which to explain in detail, 50 species found in Peninsular Malaysia, 30 species in Sabah and 20 species in Sarawak [13]. With its characteristics of being a fast-growing plant with high biomass and yield in short amount of time as well as high efficiency in just a few years, bamboo plays a big role in terms of economic resource for the locals in this country. As a matter of fact, bamboos are widely used in various application which include in construction, textiles, crafts, furniture and also cultural arts such as for writing, musical instruments or martial arts. To put it in another way, according to the BorneoTalk [14], numerous of tribes in Sarawak has been using bamboos to not only create handcrafts but also to make their very own unique traditional musical instruments, namely *Pratuokng* and *Kiromboi* which both are from the Bidayuh tribe, *Keringot* from the Penan tribe and

Suling which introduce by the Lun Bawang tribe. In the same fashion, a family from Sarawak, Ir. Ahmad Mazlan Othman [15] uses bamboos, specifically a species called "Betong" to build himself various commercialised bamboo products which to name a few are a bicycle and an electric guitar made entirely of bamboos. Table 1.1 below listed other products that are engineered from different species of bamboos found in Malaysia.

Table 1.1: Bamboo species found in Malaysia and their uses [16]

Bamboo Species	Products
Buluh Sematan *Gigantochloa scortechinii*	• Handcraft • Raw material for particle board
Buluh Beting *Gigantochloa levis*	• Shoots for food • Chopsticks
Buluh Tumpat *Gigantochloa ligulata*	• Frames • Shoots for food • Stump for plants support medium
Buluh Betong *Dendrocalamus asper*	• Shoots for food • Raw material for construction
Buluh Duri *Bambusa blumeena*	• Chopsticks • Toothpicks • Furniture • Musical instruments • Shoots for food
Buluh Semeliang *Schizostachyum grande*	• Frames • Leaves for Chinese traditional food wrapper (glutinous rice dumpling)
Buluh Dinding *Schizostachyum zollingeri*	• Handcrafts • Toothpicks

By referring to the Table 1.1 above, it is undeniable that bamboo is widely use in Malaysia especially in Sarawak itself. Interestingly enough, almost all the bamboo products, from traditional musical instruments to handcrafts are all made out of the part of bamboo called the culm. The leaves of the bamboo however, are left unuse. Which is obvious, the more bamboo product is mass-produced, the more bamboo waste which is the leaves there will be. To avoid all the unwanted bamboo waste, the unuse leaves will be use as the organic substrates in MFC and thus, will be utilized to generate bio-electricity, which will be discussed further in this research.

1.5 Problem Statement

The current power generation method such as hydropower and fossil fuels contribute to the environmental damage and production of pollution which may worsen in the next couple of years. Hence ideally, using bamboo in MFC is exemplary since it does not require agricultural land to grow which means no environmental damage will be done and might as well pollution can be control. However, according to the study made in 2014 [17], bamboo waste will unfortunately generate less electricity in comparison to when other organic substances such as the kitchen garbage is used. In other words, bamboo leaves contain less nutrient compared to other organic waste which prevent it to generate more electricity. Therefore, to improve this glucose or fly ash will be added into the bamboo leaves substance to enhance the microbial activity with the hope for it to generate higher voltage. Theoretically, glucose also helps to enhance the nutrient consists in the organic substances while fly ash promotes the degradation of organic materials which both will resulting in higher voltage.

1.6 Objectives

The objectives of this study are aimed:

i. To interpret on the performance of the single-chamber microbial fuel cell with the influence of nutrient from the bamboo leaves, rice husk and coconut waste that are being oxidized by microorganisms in the anodic chamber.
ii. To improve the generation of electricity through microbial fuel cell by adding new nutrient to the nutrients contained in the organic wastes (bamboo leaves, rice husk and coconut waste) with adding potential catalyst (organic compost).

1.7 Scope of Study

Due to its capability of delivering bioenergy, MFC is a very promising technology that will be able to use and sustain electricity in the near future. According to a study done