

FOOD WASTE FOR ELECTRICITY PRODUCTION IN
MICROBIAL FUEL CELL (MFC)

NUR ALLYSSA BINTI MOHD ZULFAKAR

BACHELOR OF ELECTRICAL ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

**FOOD WASTE FOR ELECTRICITY PRODUCTION IN MICROBIAL FUEL
CELL (MFC)**

NUR ALLYSSA BINTI MOHD ZULFAKAR

**A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering with Honours**

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

I declare that this thesis entitled “FOOD WASTE FOR ELECTRICITY PRODUCTION IN MICROBIAL FUEL CELL (MFC) is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name :

Date :

APPROVAL

I hereby declare that I have checked this report entitled “FOOD WASTE FOR ELECTRICITY PRODUCTION IN MICROBIAL FUEL CELL (MFC)” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature :
Supervisor Name :
Date :
.....

DEDICATIONS

Special dedicated to

To my beloved Mummy and Ayah

ACKNOWLEDGEMENTS

Bismillahirrahmanirrahim,

Alhamdulillah, praise to Allah S.W.T., our creator. I am so blessed that I have managed to put an end to my final year project successfully with Allah's blessings. I would like to thank Him for giving me good health and ability to go through my final year project peacefully well.

Next, I would like to extend my gratitude to my supervisor, Dr. Aziah Binti Khamis, who guided and encourage me all through the final year project and imparted in-depth knowledge in this project. I would also like to acknowledge the financial, academic and technical support to all lecturer and staff during my study in Universiti Teknikal Malaysia Melaka to complete my project.

Special thanks to my parents who always support me with the decision I took in doing my project as well as providing all my needs without hesitation during my project run. A lot of thanks to my friends for their support and sharing knowledge and information. Lastly, I am thankful to each individual whom I met ever because in every interaction with them I have memories and valuable experience to myself.

ABSTRACT

Nowadays, energy is one of the most important elements in human life. The world are facing a crisis on the insufficient of energy to support human live being as the world energy demand growth rapidly in parallel of the increase of world population rate and it will continue in the future. Microbial fuel cell (MFC) as a renewable type of energy is a collective solution of this crisis. The aim of this project is to find the new source of energy and to prove and demonstrate the generation of electricity from food waste by using MFC. The methodology of the project is to design and develop an experiment on MFC using the test parameters such as different type of food waste, different pH value for the food waste, different size of electrode and different electrode positioning in the chamber. In the whole project, it is aiming to check for the maximum production of voltage, current and power that can be produce in MFC using food waste. The data were analyzed so the result gain from the MFC can be compared to improve its efficiency. This project will use various aspects of design and operation of MFC to find the best characteristic based on the test parameters. In conclusion, the energy can be harvest from food waste by using MFC.

ABSTRAK

Dalam era masa kini, tenaga adalah salah satu elemen terpenting dalam kehidupan manusia. Dunia sedang menghadapi krisis kekurangan tenaga untuk menyokong kehidupan asas manusia seiring dengan permintaan tenaga dunia yang semakin meningkat selari dengan peningkatan kadar populasi dunia dan akan terus meningkat di masa depan. Sel bahan bakar mikrob adalah satu jenis tenaga boleh diperbaharui sebagai penyelesaian kolektif krisis ini. Tujuan projek ini adalah mencari sumber tenaga baru dan membuktikan penjanaan elektrik dari sisa makanan dengan menggunakan sel bahan bakar mikrob. Metodologi projek ini adalah untuk merekabentuk dan membangunkan percubaan pada sel bahan bakar mikrob menggunakan parameter ujian seperti jenis sisa makanan, nilai pH yang berbeza untuk sisa makanan, saiz yang berbeza untuk elektrod, dan posisi elektrod yang berbeza. Dalam keseluruhan projek, ia bertujuan untuk memeriksa pengeluaran maksimum voltan, arus elektrik dan kuasa yang boleh dihasilkan melalui sel bahan bakar mikrob menggunakan sisa makanan. Data dianalisis supaya keuntungan hasil sel bahan bakar mikrob dapat dibandingkan untuk meningkatkan kecekapannya. Projek ini akan menggunakan pelbagai aspek reka bentuk dan operasi sel bahan bakar mikrob untuk mencari ciri yang terbaik berdasarkan parameter ujian. Sebagai kesimpulan, tenaga ini boleh diperbaharui dari sisa makanan dengan menggunakan sel bahan bakar mikrob.

TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATIONS	
ACKNOWLEDGEMENTS	i
ABSTRACT	ii
ABSTRAK	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vi
LIST OF FIGURES	vii
LIST OF EQUATION	ix
CHAPTER 1 INTRODUCTION	1
1.1 Research Background	1
1.2 Problem Statement	3
1.3 Objective	5
1.4 Scope of Study	6
CHAPTER 2 LITERATURE REVIEW	7
2.1 Introduction	7
2.2 Microbial Fuel Cell	7
2.3 Microorganism in Development of Microbial Fuel Cell	8
2.4 Energy Harvesting from Food Waste by Microbial Fuel Cell	9
2.5 Effect of pH Value on Microbial Fuel Cell	9
2.6 Effect of Electrode Sizing in Microbial Fuel Cell	10
2.7 Effect of Electrode Positioning in MFC	10
2.8 Energy and Power Generation by Microbial Fuel Cell	11
2.9 Summary	12
CHAPTER 3 METHODOLOGY	13
3.1 Introduction	13
3.2 Method Used In Microbial Fuel Cell	13
3.3 General Material and Preparation on Microbial Fuel Cell	14

3.4	Type of Parameter Tested	16
3.4.1	Different Type of Food Waste and pH Value Test	16
3.4.2	Different pH Value of Food Waste	17
3.4.3	Different Electrode Sizing	17
3.4.4	Different Electrode Positioning	18
3.5	Flowchart of Project	19
3.5.1	Process involve in the project	19
3.5.2	Process Involve in Experiment A	20
3.5.3	Process Involve in Experiment B	21
3.5.4	Process Involve in Experiment C	22
3.6	Formula Used in Experiment	23
CHAPTER 4 RESULTS AND DISCUSSIONS		24
4.1	Introduction	24
4.2	Selection on Food Waste Used	24
4.3	Result and Discussion of Experiments	25
4.3.1	Experiment A	25
4.3.2	Experiment B	28
4.3.3	Experiment C	31
4.4	Summary	33
CHAPTER 5 CONCLUSION AND RECOMMENDATIONS		34
5.1	Conclusion	34
5.2	Future Recommendation	35
REFERENCES		36

LIST OF TABLES

Table 3.1	Material and Apparatus Used in Experiment	15
Table 4.1	Experiment Conducted	24
Table 4.2	Selection of Food Waste	24
Table 4.3	Average value for result obtained for type of food waste and its pH	27
Table 4.4	Average value for result obtained for different size of electrodes	30
Table 4.5	Average result obtained for Electrode Positioning	32

LIST OF FIGURES

Figure 1.1	World population and world energy demand growth	1
Figure 1.2	Malaysia's Electric Generation 2015	2
Figure 1.3	Waste Composition in Malaysia	4
Figure 1.4	Food Waste Per Day in Malaysia	5
Figure 2.1	Example of horizontal and vertical configurations	11
Figure 3.1	The Schematic Diagram of Two Chamber Microbial Fuel Cell	14
Figure 3.2	Block Diagram for Flow of Project	14
Figure 3.3	Experiment of Microbial Fuel Cell	16
Figure 3.4	Electrode size: (a) Small size = 0.0724m^2 , (b) Big size = 0.148m^2 , (c) Small size with spaces = 0.0725m^2 (same size as small) but consist of three electrodes that have been space for 2 cm each electrode	17
Figure 3.5	Electrode positioning: (a) Horizontal electrode position, (b) Vertical electrode position	18
Figure 3.6	Process involve in the project	19
Figure 3.7	Process involved in experiment A	20
Figure 3.8	Process involved in experiment B	21
Figure 3.9	Process involved in experiment C	22
Figure 4.1	Comparison of Voltage Produce Per Day by Tomato, Apple and Milk	25
Figure 4.2	Power Density vs Current Density for Tomato	26

Figure 4.3	Power Density vs Current Density for Apple	26
Figure 4.4	Power Density vs Current Density for Milk	27
Figure 4.5	Comparison of Voltage Produce Per Day by Small, Big and Small Size with Spaces	28
Figure 4.6	Power Density vs Current Density for Small Size Electrode	29
Figure 4.7	Power Density vs Current Density for Big Size Electrode	29
Figure 4.8	Power Density vs Current Density for Small Size Electrode with Spaces	30
Figure 4.9	Comparison of Voltage Produce Per Day by Horizontal and Vertical Position	31
Figure 4.10	Power Density vs Current Density for Horizontal Electrode Position	32
Figure 4.11	Power Density vs Current Density for Vertical Electrode Position	32

LIST OF EQUATION

2.1	General reaction in anaerobic chamber	7
2.2	General reaction in aerobic chamber	8
2.3	Current density at anode	11
2.4	Current density at cathode	12
3.1	Surface area	23
3.2	Current	23
3.3	Current Density	23
3.4	Power	23
3.5	Power Density	23

CHAPTER 1

INTRODUCTION

1.1 Research Background

In this new modern era, the world population growth rapidly as there were less than one billion humans living on earth 200 years ago [1]. Figure 1.1 shows the world population and energy consumptions demand growth chart from 1900 until 2100 expected growth [2]. Today, the world population increase up to 7 billion and in 2100 the growth expected to be 9 billion of humans living on earth.

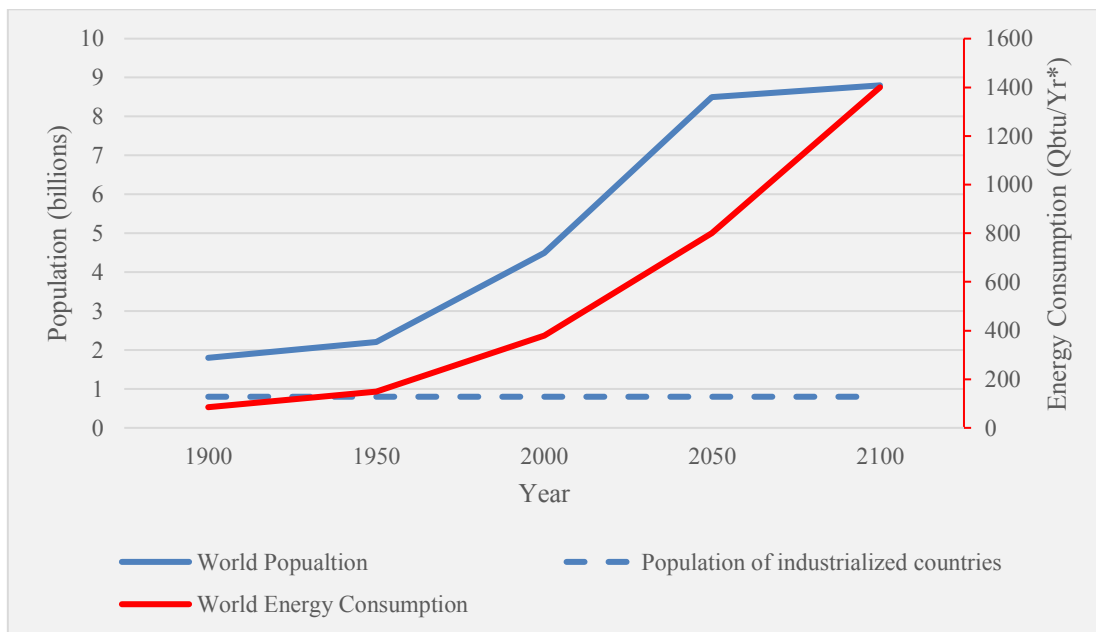


Figure 1.1 World population and world energy demand growth [2]

As shown in Figure 1.1, the energy consumption is increase and this led to insufficient energy to support human live being on earth. Year by year the energy demand growth steeply as the world population increase rapidly by year. The energy consumption is expected to increase two times in year 2100 from today, 2019.

Although the world today has created many alternatives in generating renewable energy such as hydroelectric energy, solar energy, wind energy and many more, this renewable energy still cannot support the increasing demand in energy sources due to rapid population growing rate.

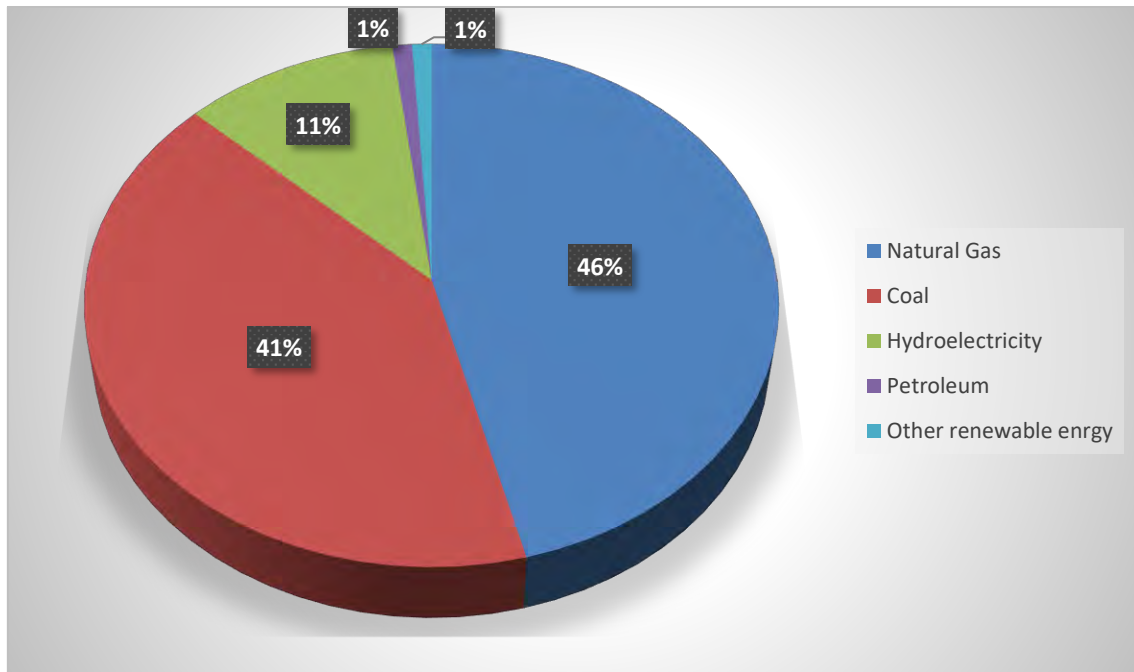


Figure 1.2 Malaysia's Electric Generation 2015 [4]

In Malaysia, the generation of electricity depends on three major fossil fuels sources which are coal, natural gas and fuel-oil [3]. Figure 1.2 shows the Malaysia's electric generation statistic in 2015 [4]. In the end of 2014, these three major fossil fuels sources made up of 81% of electric generation capacity and increase to 88% in 2015 [3]. It can be see that power plant generation in Malaysia still relies on large quantity of natural gas. As parts of Malaysia's effort to reduce carbon dioxide, to cut greenhouse gas emissions intensity of gross domestic product and to diversify its electricity fuel mix, Malaysia encourages people to invest other types of renewable energy projects.

In other alternatives for the Malaysia's encouragement, microbial fuel cell (MFC) can be construct and be one of the electricity source production. The ability to generate power from organic or inorganic compounds via microorganism makes MFC a trending projects among scientist. Microbial fuel cell is a bio-electrochemical device that exploit the ability of microbial respiration to convert any organic substrates directly to electrical energy [5]. This process will convert chemical energy to electrical energy by applying oxidation reduction reaction also known as redox reaction. Redox reaction is a process involving oxidation where the loss electrons happens and reduction where the gaining of electrons happen.

Briefly, microbial fuel cell can be used as a renewable energy to overcome the insufficiency of energy demand as MFC works in the generation of electricity production through microorganisms. In anodic chamber, substrates are oxidizing to produce electrons and protons by microorganisms while producing carbon dioxide as oxidation product. Electrons that are produces from anode chamber transfer to cathode chamber through external circuit. The oxygen provided in cathode chamber helps in migration of protons across the proton exchange membrane (PEM) to combine with electrons to form water. Therefore, the current flow from positive terminal to negative terminal and this direction is opposite to electron flow. And this is how the MFC works [6].

1.2 Problem Statement

New source of energy needs to be developed to support the Malaysia's energy consumptions. Renewable energy is the easiest way to focus on for the new development. The advantage of renewable energy is it will never run out as it is sustainable. This implies that they do not deplete over a lifetime and there is zero possibility that they will run out. Renewable energy requires less maintenance than traditional generator. More importantly, it is an eco-friendly as it is a clean source where it has low or zero carbon and greenhouse emission. Thus, it will give minimal impact on the environment [7].

Although there are many advantages on the renewable energy, it also has its own disadvantages. One of the disadvantages of renewable energy is the electricity generation capacity is still not large enough. To generate large quantities of power in renewable energy is still challenging compared to traditional forms of energy generation like fossil fuel.

Renewable energy also can be unreliable as it totally depends on the climate to be able to harness any energy such as sun and wind. In case the weather is not good enough, the ability to generate electricity of renewable energy technologies would be lack. However, there are one of the renewable energies that always has it ‘fuel’ and it is to generate energy from food waste.

Why food waste? From The Star statistical value stated that the amount of food waste composition in Malaysia is the highest among any other waste composition which is 44.5% [8]. Therefore, food waste is choosed as substrate. Instead of the government waste it and decompose at disposal area without any action taken, microbial fuel cell can be invented to generate electricity from food waste.

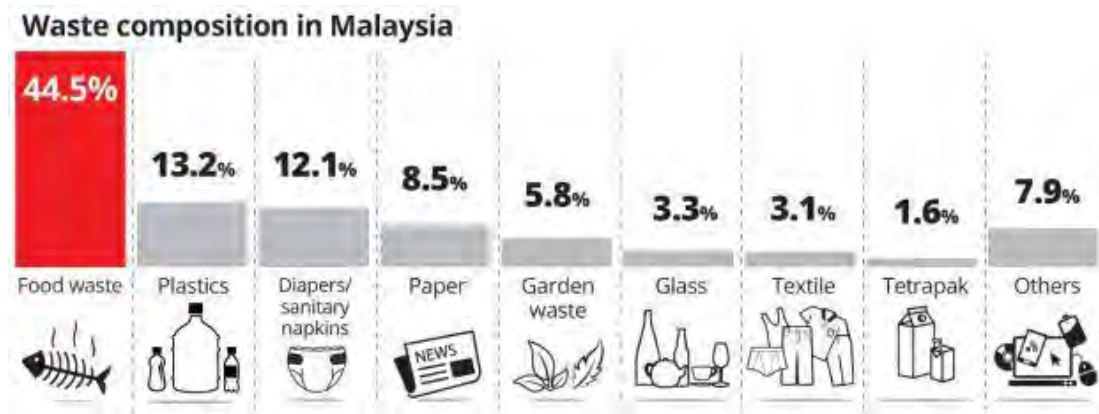


Figure 1.3 Waste Composition in Malaysia [8]

In Malaysia, amount of food waste has increased steeply in just a few years. In 2009, food waste averaged at around 450 tonnes a day and the number increased doubled in 2011 and in 2013, the amount of food waste multiplied to 15 times a day. This statistic is disturbing as the amount of food waste can feed 7.5 million people a day [9].



Figure 1.4 Food Waste Per Day in Malaysia [9]

1.3 Objective

The objectives of the project are described as follows:

- i. To develop an effective Microbial Fuel Cell system using two chamber of food waste such as fermented apple, tomato and milk.
- ii. To identify the correlation of power density based on different kind of test parameters such as different type of food waste, different pH value, different electrode size and different electrode position.
- iii. To analyze the best characteristic performance based on the proposed parameters test.

1.4 Scope of Study

The main focus of this project is the development of energy from food waste using MFC. A systematic approach of MFC is developed to investigate the way of generated energy from food waste. Therefore, this project will focus on the making of MFC and the improvement. There are four parameters to be tested in this project. The parameters are as follow:

- Different type of food waste
- Different pH value for the food waste
- Different electrode size test on MFC
- Different electrode positioning in MFC

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter explained and discussed about the past related works and projects regarding a microbial fuel cell proposed by various researchers and developers.

2.2 Microbial Fuel Cell

Microbial fuel cell is bio-electrochemical device that use the power of microorganism respiration system to convert organic substrates directly into electrical energy or to be exact it converts chemical energy into electricity using oxidation reduction reaction [10]. Oxidation reduction reaction also know as redox reaction is a process involve the transfers of electron where the electrons are loss or gain in two different species [11]. The operational and functional advantages of MFC are the catalysts used are readily available microbes and fuel used are organic waste matter. It is not like Hydrogen Fuel Cell as it does not require highly regulated distribution systems. Compare to other fuel cell like Enzymatic Fuel Cell, MFC has the highest conversion efficiency in harvesting up to 90% of the electrons from the bacterial electron transport system [12].

In anode chamber, microorganisms play important roles as it will generate electrons. The generated electrons are utilized and it is transfer from anode to cathode through proton exchange membrane to complete the circuit. This chamber is also known as anaerobic chamber. All the essential conditions to decompose the organic substrate are provided in anaerobic as it is the main part of MFC. The general reaction in anaerobic chamber is as equation follows [13]:



Anaerobic Environment

In cathode chamber or aerobic chamber, it receives the proton and electron produces in the anode chamber as it migrates through the proton exchange membrane which will complete the electrical circuit. A steady current is produced and it is travelling through external circuit which wire connecting the anode and cathode. The generated electrons travel to aerobic chamber and transmit onto oxygen. It will produced positive ions in anaerobic in the following reaction to form water which spreads by the way of the ion permeable membrane on anaerobic along with the help of catalyst as follows [13]:



2.3 Microorganism in Development of Microbial Fuel Cell

In MFC, microorganism is the most important element in generating electricity. There are two types of microbes that can be used. Firstly, using anode as terminal electron acceptors, microbes can directly transfer electron to anode. Second is microbes that use mediators to transfer electrons to anode.

The stable and high coulombic efficiency microbes can transfer electron directly to cathode as it is effective and form film in anode. For those microorganisms that can't transfer directly to anode, it will use mediator to capture the electron from the membrane of the microorganism. Good mediator with a low costing has five characteristics as follows:

- Permeable cell membrane
- Electron affinity is more than electron carriers of the electron transport chains
- High electrode reaction rate
- Well soluble
- Completely non-biodegradable and non-toxic to microbes

2.4 Energy Harvesting from Food Waste by Microbial Fuel Cell

Food processing waste are wanted for bioenergy production because it has content that favor for biodegradation such as moisture content, rich organic content and high carbon to nitrogen ratio. Various food wastes have been tested as MFC fuels including canteen-based food waste, molasses wastewater, starch processing wastewater, brewery wastewater palm oil mill wastewater and dairy wastewater. The most favorable food waste for electricity production are food waste that contains high percentage of easily degradable carbohydrates such as dairy wastewater, brewery wastewater and molasses compare to those rich in cellulose and lipids [14].

There is also a research that states foods that release sugar faster will produce more energy as it has higher glycemic index. Sugar that contain in fruits had a greater output than meats and vegetables [15]

2.5 Effect of pH Value on Microbial Fuel Cell

pH is a measure of hydrogen ion concentration. It is also a numerical measure of the acidity or alkalinity of a solution. Usually it is measured on a scale of 0 to 14. Solution with low concentration of hydrogen ions have a high pH while a high concentration of H^+ ions have a low pH. Acidic solution have pH lower than 7 while alkaline have pH higher than 7 as 7 is neutral solution.

Among many factors, to be crucial to MFC performance, anodic pH has also been suggested because growing pH conditions are controlling the microbial metabolic activity. Currently, some reports showed that under alkaline conditions, MFC exhibit better performance when operating [16]. There is also a report short term test that at pH level 9.5, MFC has the highest power production. But anodic bacteria were affected and power generation terminated at the pH higher than the optimal one [17].

2.6 Effect of Electrode Sizing in Microbial Fuel Cell

Application of MFC will require the design of compact reactor, the use of inexpensive materials, and a better understanding of how to achieve optimum conditions for power generation. Electrode design is critical given the need for larger power production and the contribution of materials used to overall reactor cost. A suitable electrode is an electrode that are ideal for scaling-up MFC as they have large porous surface area, noncorrosive, low resistance and good electrical conductivity.

The use of smaller electrode with space made possible to maintain closer electrode spacing on average and would allow for more compact design without the need of separator. Based on the better performance of smaller electrode with space configuration, it can be concluded that the location of the geometric center of mass of anode also had a significant effect on power generation. The use of smaller electrode with space may also benefit of a larger electrode of current collector [18].

2.7 Effect of Electrode Positioning in MFC

Increasing the numbers of the electrode (multi-electrode system) rather than increasing the size of electrode seems to be more effective. The installation of the electrode at different depth may also influence the performance of MFC. Therefore, vertical (electrodes at different depth) and horizontal (electrodes at the same depth) configurations are compared. It can be seen that the electrodes present in the vertical configuration produced more energy. It can also be deduced that low resistance with high capacitance gave high energy generation. But this statement cannot be generalized in positional effect. Since different positions in the reactor had different substrate diffusion rate which also acts as limiting factor. Therefore, energy generation provides influence of different position in the reactor.