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

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A report submitted
in partial fulfillment of the requirements for the degree of
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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.

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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.

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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 menigkat selari dengan peningkatan kadar populasi dunia dan akan terus menigkat 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.

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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.

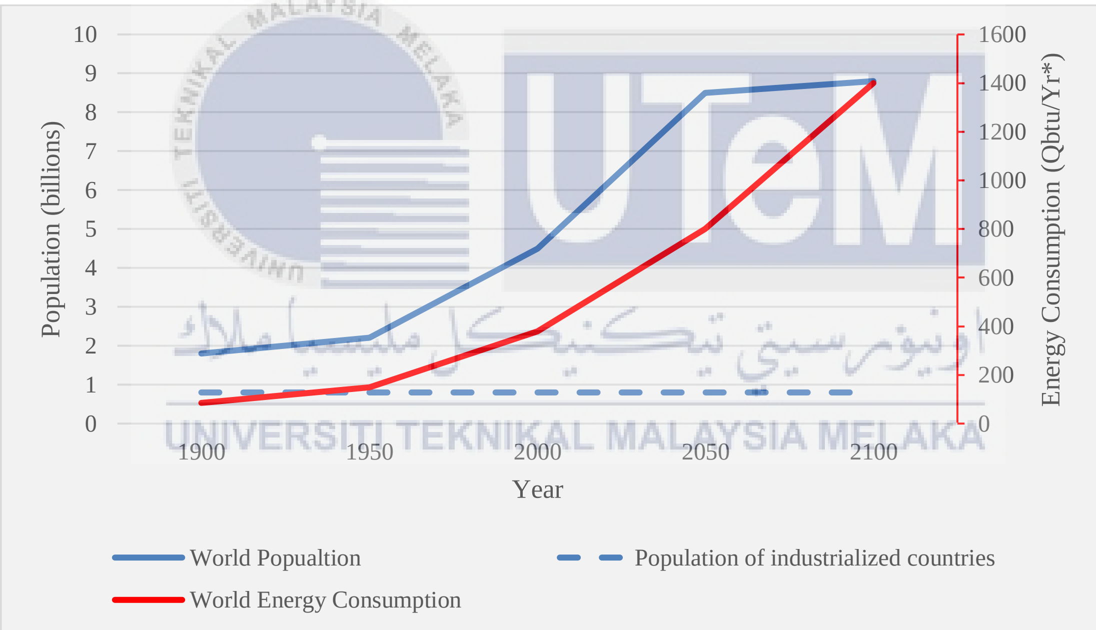


Figure 1.1 World population and world energy demand growth [2]

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.

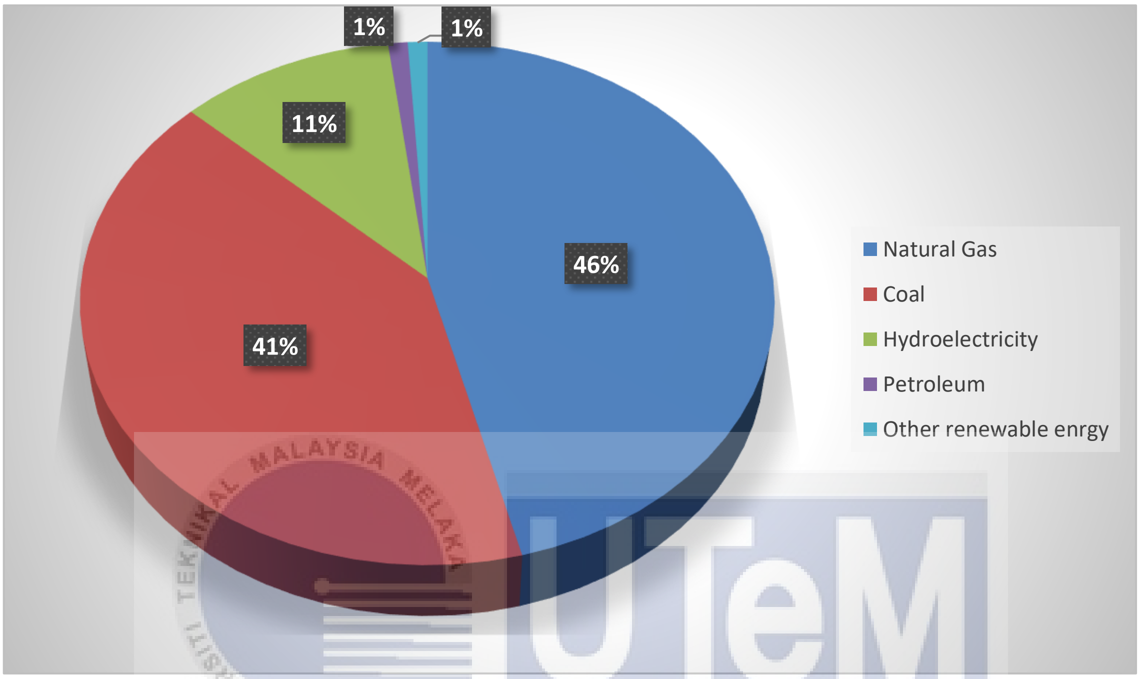


Figure 1.2 Malaysia's Electric Generation 2015 [4]

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.

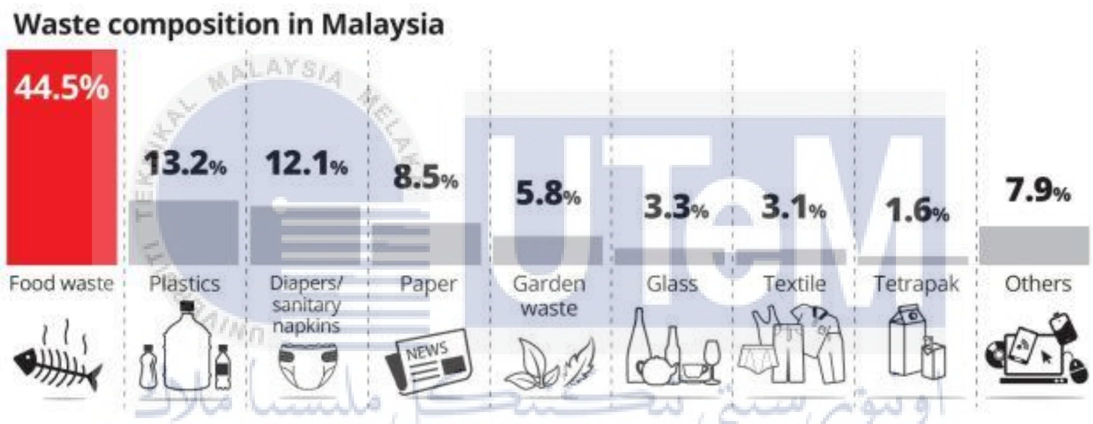


Figure 1.3 Waste Composition in Malaysia [8]

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]:

$$\text{Biodegradable Organic} \xrightarrow{\hspace{2cm}} CO^2 + H^+ + e^- \tag{2.1}$$

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]:

$$2O_2 + 8H^+ + 8e^- \longrightarrow 4H_2O \qquad (2.2)$$

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 effectives 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 carries 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 o 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.

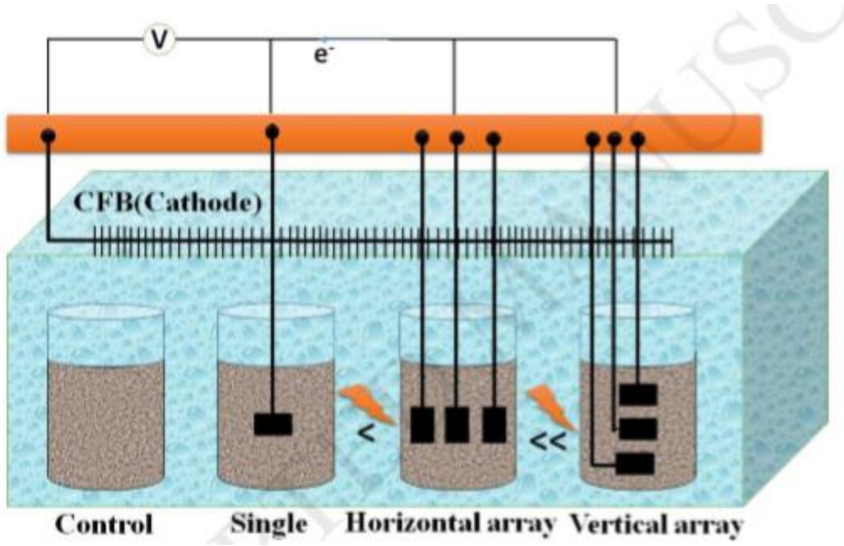


Figure 2.1 Example of horizontal and vertical configurations [19]

Based on Figure 2.1, vertical and horizontal configurations are different because of hydraulic pressure difference on the electrode. In horizontal configuration, all electrodes are at same pressure, whereas in vertical configuration all electrodes are at a different pressure. Pressure difference decreases the diffusional resistance, which would lead to less accumulation of ions. In multi-electrodes configuration, switching of the electrodes can also be utilized to enhance the performance and for identification of malfunctioning electrodes. The best configuration for the future development of MFC is vertical configuration [20].

2.8 Energy and Power Generation by Microbial Fuel Cell

Current density and power density are the most commonly used parameters, which principally show the amount of electricity produced from MFC. Current density represents the current in terms of unit surface area of electrode. Usually current is normalized by the anode surface area whereas surface of area is used when the reaction is rate limiting step. Thus, the current density is calculated as:

$$I_{anode} = \frac{I}{A_{anode}} \tag{2.3}$$

$$I_{cathode} = \frac{I}{A_{cathode}} \tag{2.4}$$

where I is the current (A), I_{anode} (Am^{-2}), Icathode (Am^{-2}), and current density normalized by the anode surface area (Aanode, m^2), and surface area cathode (Acathode, m^2) respectively.

Power density is used to evaluate the power output of MFC. Power density is expressed as the power (P,W) provided by per unit surface area of electrode. The maximum power density (P_{max}) can be achieved when the internal resistance is equal to the external resistance of an MFC.

2.9 Summary

The reviewed of several projects is significance for project development. Generate energy from food waste by using MFC is a project which combine mechanism and hardware development.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the development and implementation of purpose generating electricity via food waste product. It will discuss about the method used in this project and general preparation needed to conduct the experiment. Formula used for calculation in obtaining results also shown in this chapter. It starts from understanding the concept to the final stage of implementation hardware.

3.2 Method Used In Microbial Fuel Cell

The main focus of microbial fuel cell is in its chamber. In this project, two chambers of MFC is used as it gives more output than single chamber. The conventional design of microbial fuel cells consists of one anode chamber connected to one cathode chamber by a bridge and separated by a proton/cation exchange membrane. Proton/cation exchange membrane can be replaced by a salt bridge. Salt bridge is a device that is used to prevent the electrical contact between two electrolytes, which consisted of a tube filled with cloth soak in saltwater. The function of salt bridge is to maintain the charge of electrolyte as the electrons are moving from one cell to another.

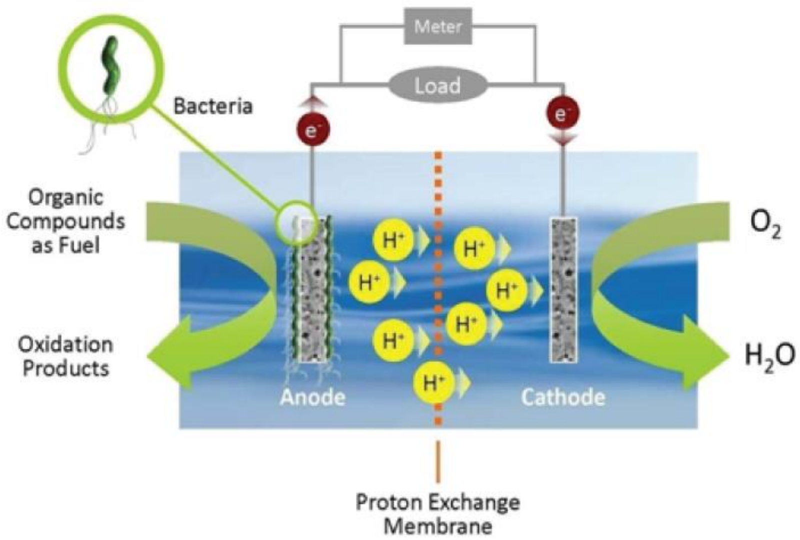


Figure 3.1 The Schematic Diagram of Two Chamber Microbial Fuel Cell [19]

As shown in Figure 3.1, the MFC is divided into two chamber which is anode chamber (anaerobic) and cathode chamber (aerobic). In anaerobic, the food waste is placed in this chamber and being sealed to avoid oxygen. While in aerobic chamber, it contains distilled water and it is being supply by oxygen. The microorganism in the food waste attached in anode metal while decomposed organic matter and generate electrons. The generated electrons in anode are migrated to cathode flowing through the wire and the ion flow through the proton exchange membrane which complete the electrical circuit.

3.3 General Material and Preparation on Microbial Fuel Cell

For this project, several experiments were conducted and the result then evaluated to find the best and suitable ways to generate electricity. The flow of the project is as shown in the block diagram in Figure 3.2.

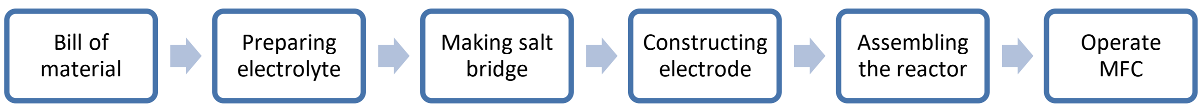


Figure 3.2 Block Diagram for Flow of Project

Before the experiment were conducted, bill of material needs to be done. The list of material and apparatus used are listed in Table 3.1:

Table 3.1 Material and Apparatus Used in Experiment

Material and apparatus used for the experiment
• Copper plate • Container • Pipe • Copper wire and crocodile clips • 500ml of distilled water • 500ml of different type of food waste • pH meter and pH solution • Cloth soak with salt water • Multimeter

Next, the preparing of electrolyte consists of two solutions; distilled water and food waste. Importantly, the food bought needs to be fermented for about 10 days to make it as an example of food waste. One container is filled with 500ml of distilled water while the other one is filled with 500ml of food waste that has been blended separately for each type. Then, electrolytes are tested its pH value by using the pH solutions and pH meter.

The salt bridge preparation in this project used a tube that connects to container. In those tubes contains a cloth that have been soak with saltwater for 10 minutes. Then, the electrode is prepared. For this project, copper plate that have been folded into few layers are used as an electrode to generate electricity in MFC. After all preparations are done, all the reactors are assembled before MFC is operated as shown in Figure 3.3. Not to forget the solution of food waste are mix well with 50ml booster called Super Bacti Bravo. The MFC is operated for several days and been observed for every 12 hours. The result then is evaluated by amount of electricity produced per day.

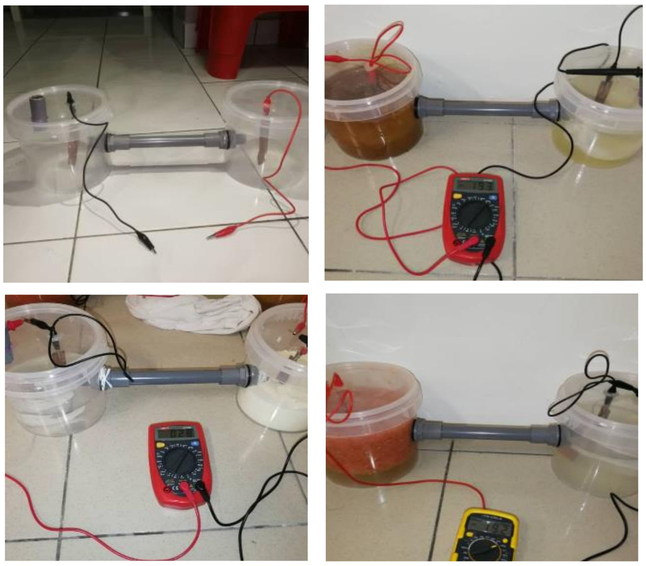


Figure 3.3: Experiment of Microbial Fuel Cell

3.4 Type of Parameter Tested

3.4.1 Different Type of Food Waste and pH Value Test

These different types of food waste and its pH value parameter are tested to determine the best type of food that produce greatest electricity. These experiment is observe for 7 days only. There are 3 types of food waste used in the experiment:

- Dairy product
- Fruits
- Vegetable

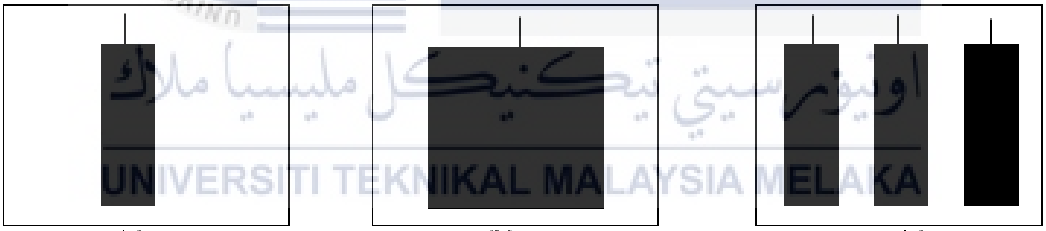
3.4.2 Different pH Value of Food Waste

Regarding the type of food waste, second parameter tested is different of pH value on the type of food waste. All food waste consists of different type of pH value. These experiment is observe for 14 days only. pH value for the food waste are as follows:

- Dairy product is between 6.3 to 8.5 where is more to alkaline
- Fruits are between 3.2 to 4.1 which it are the most acidic
- Vegetables are between 4.2 to 5.0 as it is not a strong acid

3.4.3 Different Electrode Sizing

This parameter is test on the electrode sizing in MFC. There are three sizes to be tested which is small, big and small size with spaces to determine the best size of electrode to install in MFC. The sizing of the electrode is refer to the total surface area of electrode. The total surface area of the electrode are shown in Figure 3.4.



(a) (b) (c)

Figure 3.4: Electrode size (a) Small size = $0.0724m^2$, (b) Big size = $0.148m^2$, (c) Small size with spaces = $0.0724m^2$ (same size as small) but consist of three electrodes that have been space for 2 cm each electrode

3.4.4 Different Electrode Positioning

The fourth parameters tested are electrode positioning. The positioning of electrode will involve in both chambers. There are two positions to be tested as shown in Figure 3.5.

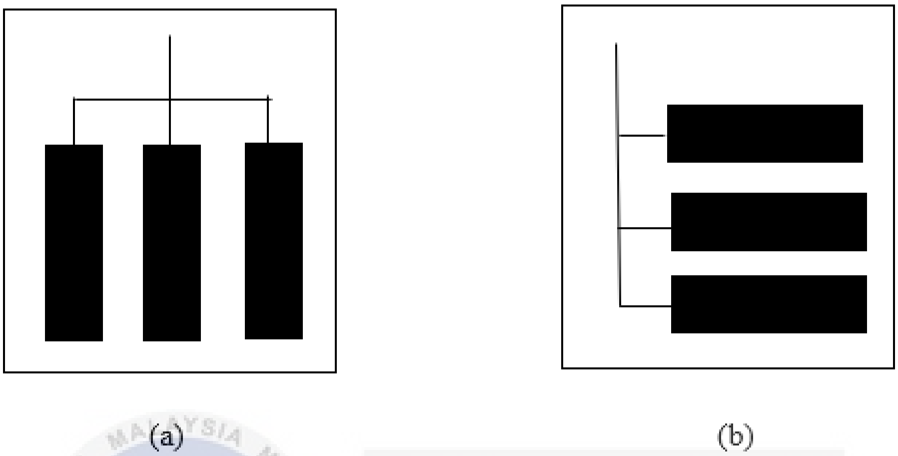


Figure 3.5 Electrode positioning : (a) Horizontal electrode position, (b) Vertical electrode position

3.5 Flowchart of Project

3.5.1 Process involve in the project

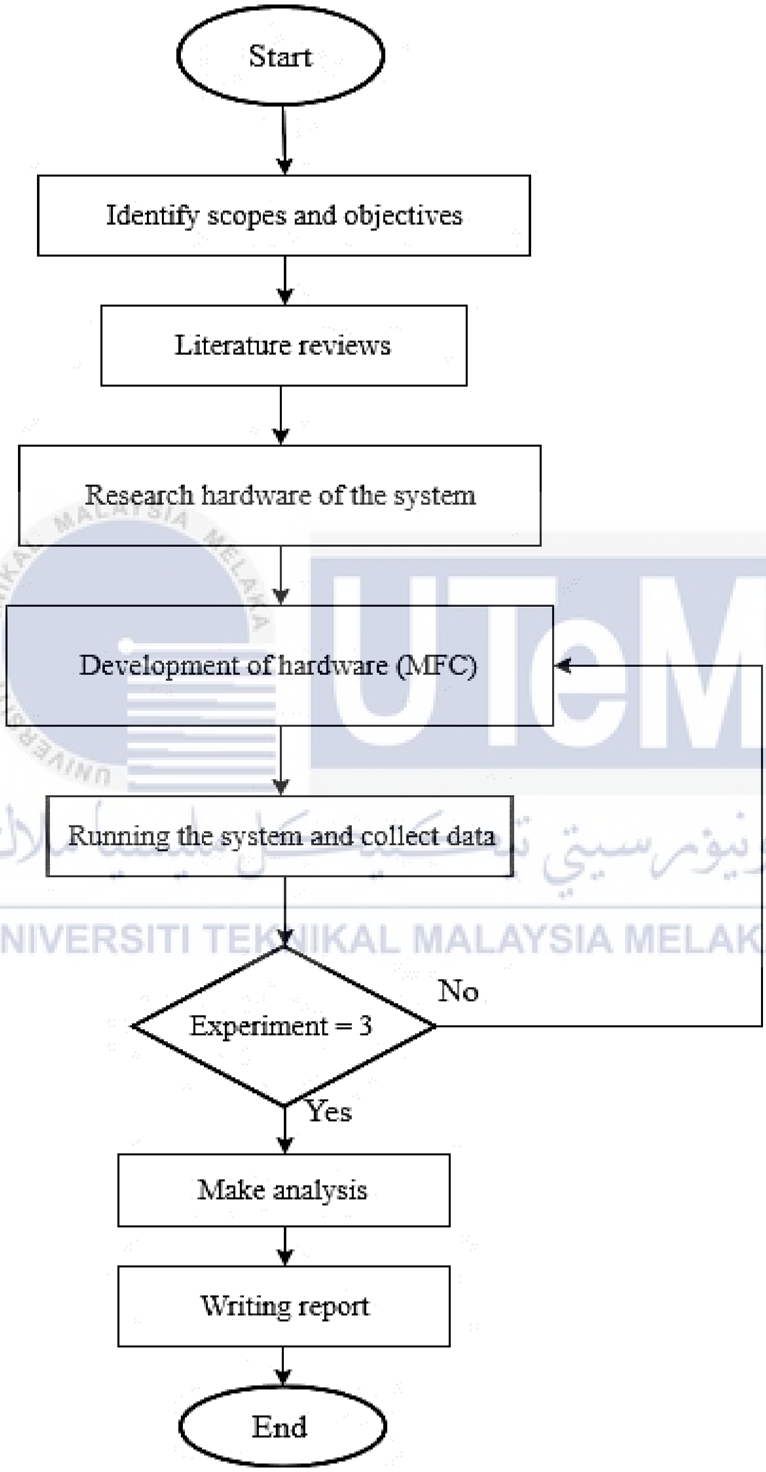


Figure 3.6 Process involve in the project

3.5.2 Process Involve in Experiment A

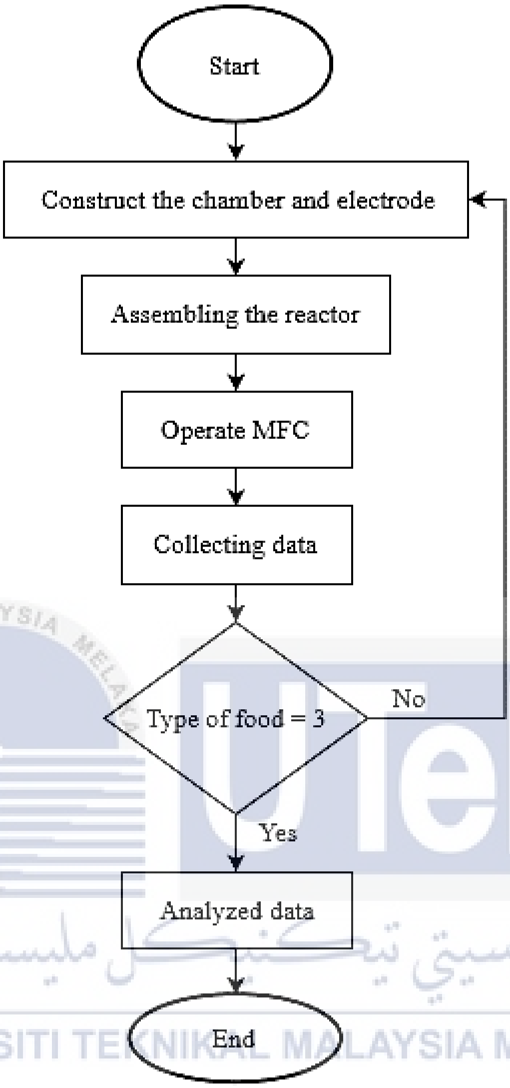


Figure 3.7 Process involved in experiment A

Figure 3.7 shows the process involve in Experiment A. Experiment A focus on the effect of the type of food waste and its pH value on MFC. Every MFC will be test with 3 type of food which is fruit, vegetable and dairy product. The project durations are 7 days for each type of food waste and the data collection is every 12 hours.

3.5.3 Process Involve in Experiment B

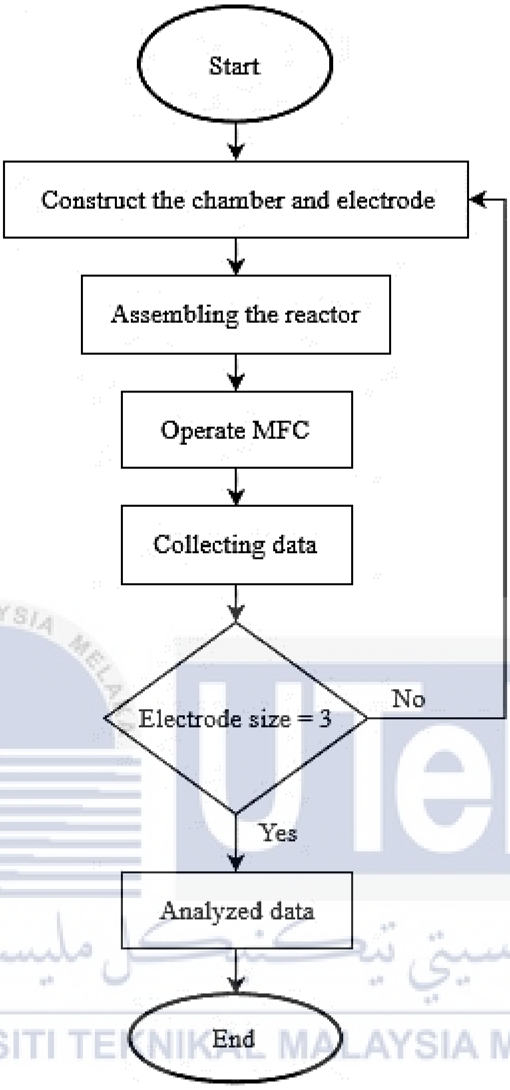


Figure 3.8 Process involved in experiment B

Figure 3.8 shows the process involve in Experiment B. Experiment B focus on the effect of the different size of electrode on MFC. Every MFC will be test with 3 size of electrode which is small, big and small size with space. The project durations are 14 days for each type of electrode size and the data collection is every 12 hours.

3.5.4 Process Involve in Experiment C

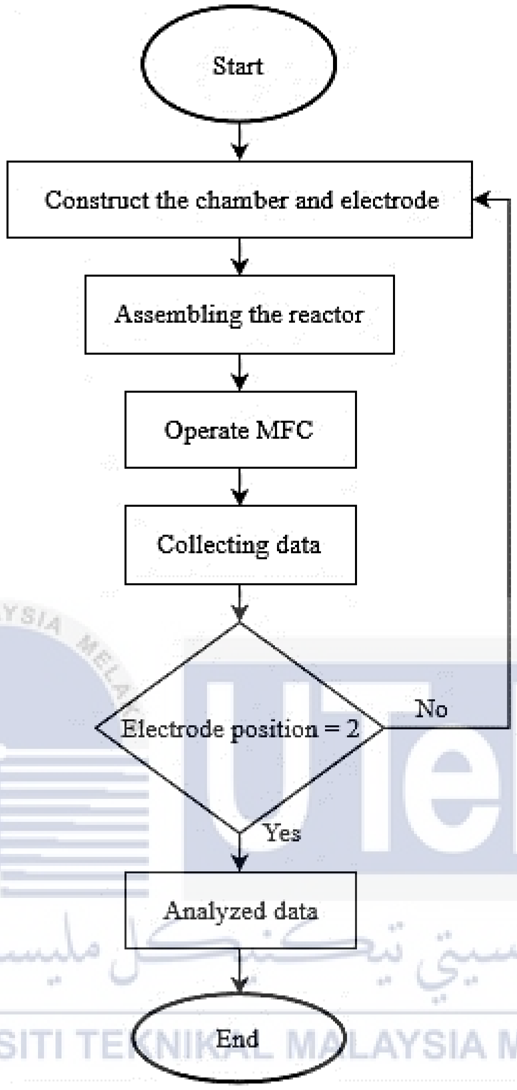


Figure 3.9 Process involved in experiment C

Figure 3.9 shows the process involve in Experiment C. Experiment C focus on the effect of the type of food waste and its pH value on MFC. Every MFC will be test with 2 different electrode position which is horizontal and vertical. The project durations are 14 days for each type of electrode position and the data collection is every 12 hours.

3.6 Formula Used in Experiment

For this project, the results of the experiment are voltage, current density and power density. The resistor used in the experiment is 100 Ω. The results will be plotted in two graphs as follows:

- Voltage vs Days
- Power Density vs Current Density

The formula used to calculating surface area of electrode are as follows:

$$\text{Surface area} = 2\,((\text{Lenght X Width})+(\text{Length X Height})+(\text{Height X Width})) \quad (3.1)$$

The formula used for calculating current density are as follows:

$$Current = \frac{Voltage}{Resistor} \quad (3.2)$$

$$Current\ Density = \frac{Current}{Surface\ Area} \quad (3.3)$$

The formula used for calculating power density are as follows:

$$Power = \frac{Voltage}{Current} \quad (3.4)$$

$$Power\ Density = \frac{Power}{Surface\ Area} \quad (3.5)$$

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter showed the result that has been discuss in chapter 3 in order to achieve the objective of this study. The result shows the data of the voltage, current density and power density. The experiment focus on three different variables to be tested as Table 4.1 below:

Table 4.1 Experiment conducted

Experiment	Variables
Experiment A	Effect on type of food waste and its pH value
Experiment B	Effect on electrode sizing
Experiment C	Effect on electrode positioning

The data shows the difference of variables that can affect the production of energy. This data will be collected to determine the effect of variable in MFC and the result was been analyze.

4.2 Selection on Food Waste Used

The food waste used are select based on the parameters present which are type of food waste and pH value of food waste. The food used are as listed in Table 4.2:

Table 4.2 Selection of Food Waste

Type of food waste	**Food waste used**	**pH value of food waste**
Fruits	Apple	3.9
Vegetables	Tomato	4.5
Dairy product	Milk	6.6

The food waste are select based on the researched that have been made to investigate which type of food waste best used in MFC. The hypothesis concluded from some researches are food that release sugar faster generate more electricity and some study said that dairy product with large amount of carbohydrates generate more electricity. While pH value is selected to a large difference of value to compare it either higher pH value has much more production of electricity or lower pH value.

4.3 Result and Discussion of Experiments

4.3.1 Experiment A

In this section, the results of the experiment A which it is tested on the effect of type of food waste and its pH value are plotted in Figure 4.1 to show the comparison result of food waste used.

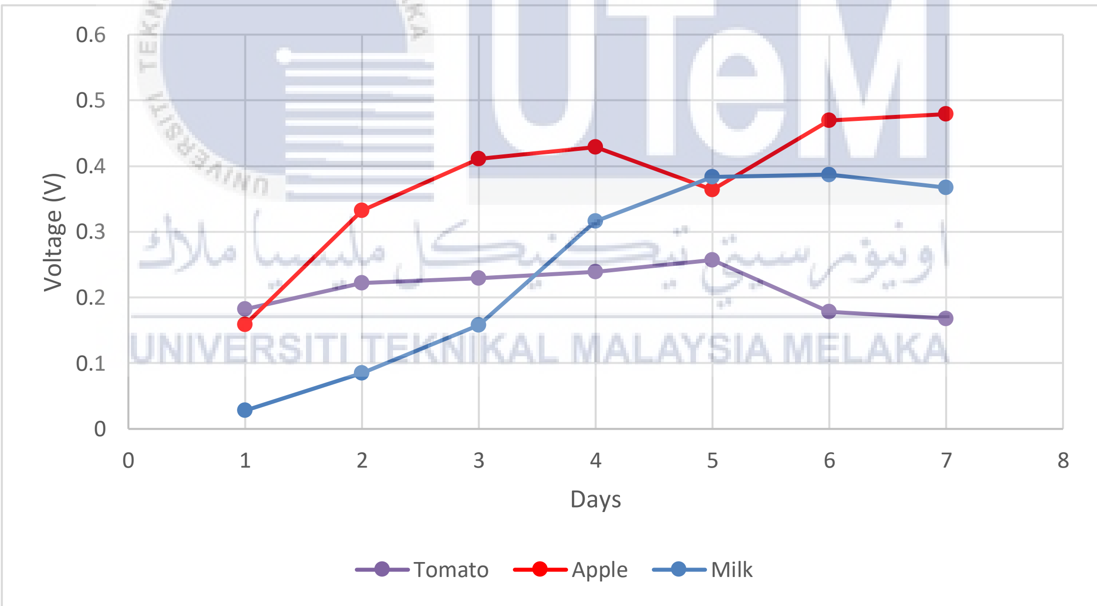


Figure 4.1 Comparison of Voltage Produce Per Day by Tomato, Apple and Milk

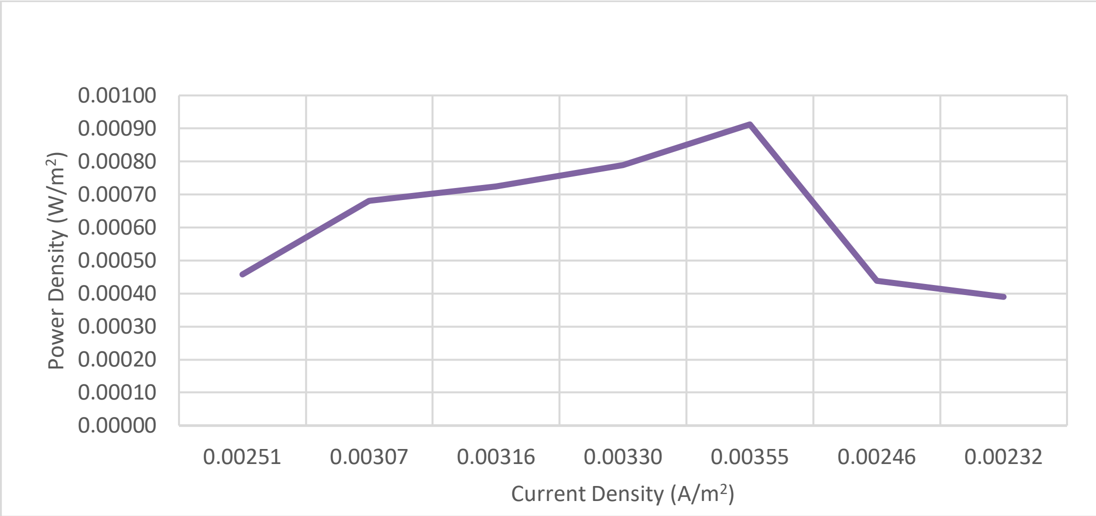


Figure 4.2 Power Density vs Current Density for Tomato

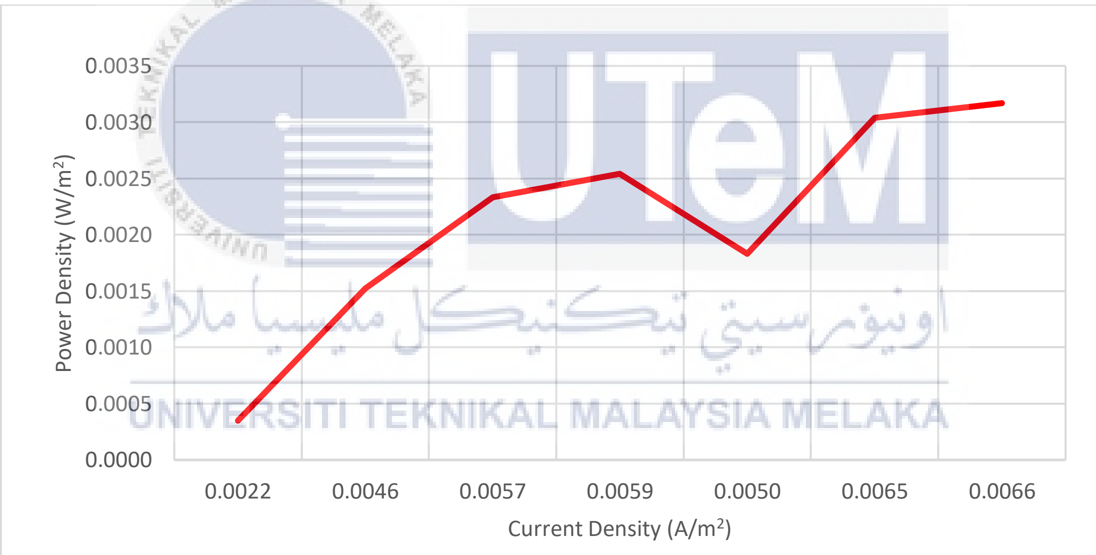


Figure 4.3 Power Density vs Current Density for Apple

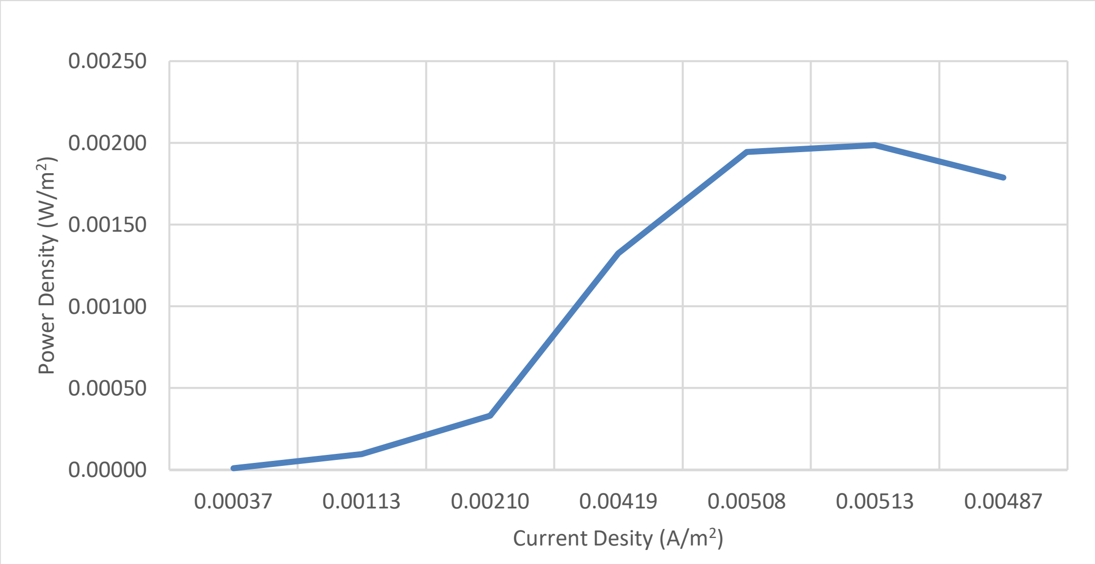


Figure 4.4 Power Density vs Current Density for Milk

Table 4.3 Average value for result obtained for type of food waste and its pH

Experiment	**Voltage (V)**	**Current (I)**	**Current Density (mA/m^2)**	**Power Density (mW/m^2)**
Tomato	0.2107	0.0021	2.910	0.627
Apple	0.3776	0.0038	5.215	2.112
Milk	0.2463	0.0025	3.266	1.069

Table 4.3 shows the data average of the voltage, current, current density and power density produce by the food waste used in the experiment which is tomato, apple and milk. From Figures 4.2, 4.3, and 4.4, the higher rate of voltage, current density and power density produce in MFC is when apple is used. Apple is a fruit with the lowest pH value. Hence, it can be concluded that apple can produce more electricity than other food waste. The hypothesis that can be made from the experiment is food which release sugar faster can generate more electricity than other foods. Other hypothesis that relate in this experiment is different type of food waste with different pH value effect the efficiency of the MFC to generate energy.

4.3.2 Experiment B

In this section, the results of the experiment B which it is tested on the effect of electrode size are plotted in Figure 4.5 to show the comparison result of electrode size used which consists small size, big size and small sizes with spaces. For this experiment, the type of food waste used is apple for all the electrodes size due to the best food waste energy production. This experiment is conducted using the best results of type of food waste used from the previous experiment in attempt to increase the power generation of MFC.

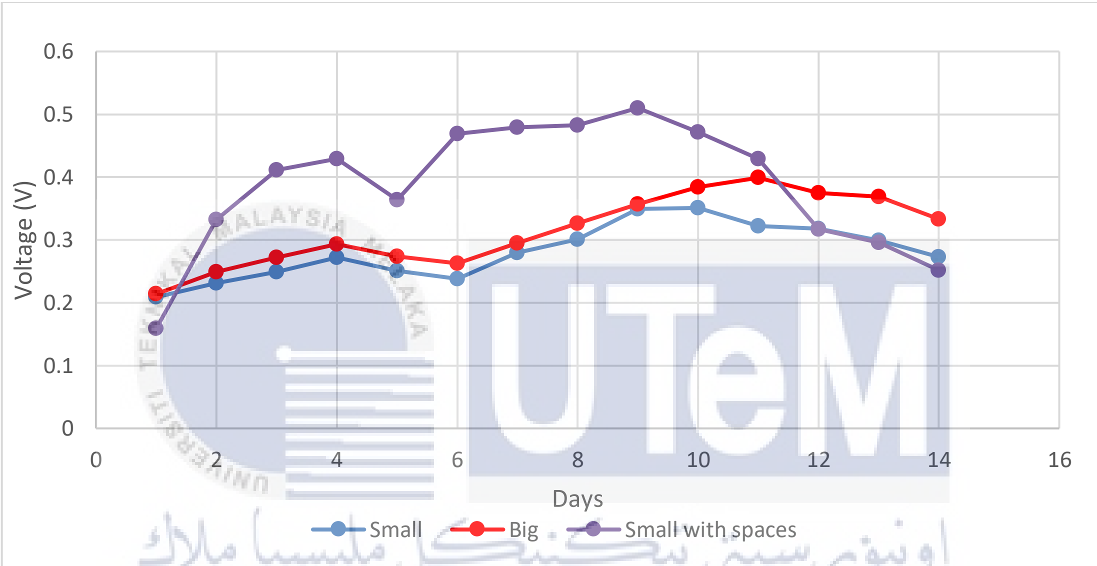


Figure 4.5 Comparison of Voltage Produce Per Day by Small, Big and Small Size with Spaces

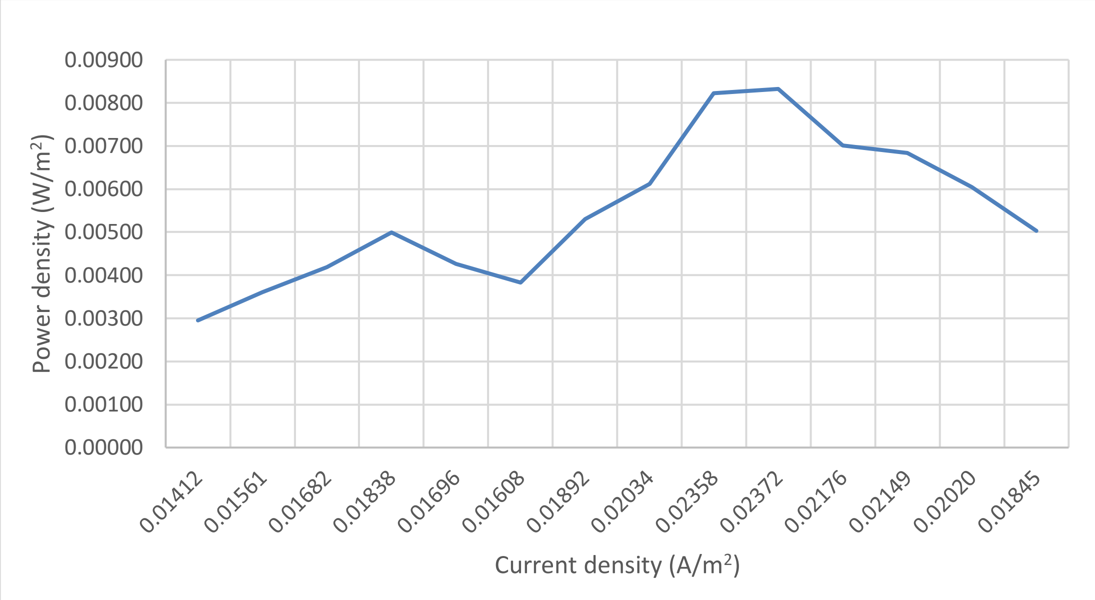


Figure 4.6 Power Density vs Current Density for Small Size Electrode

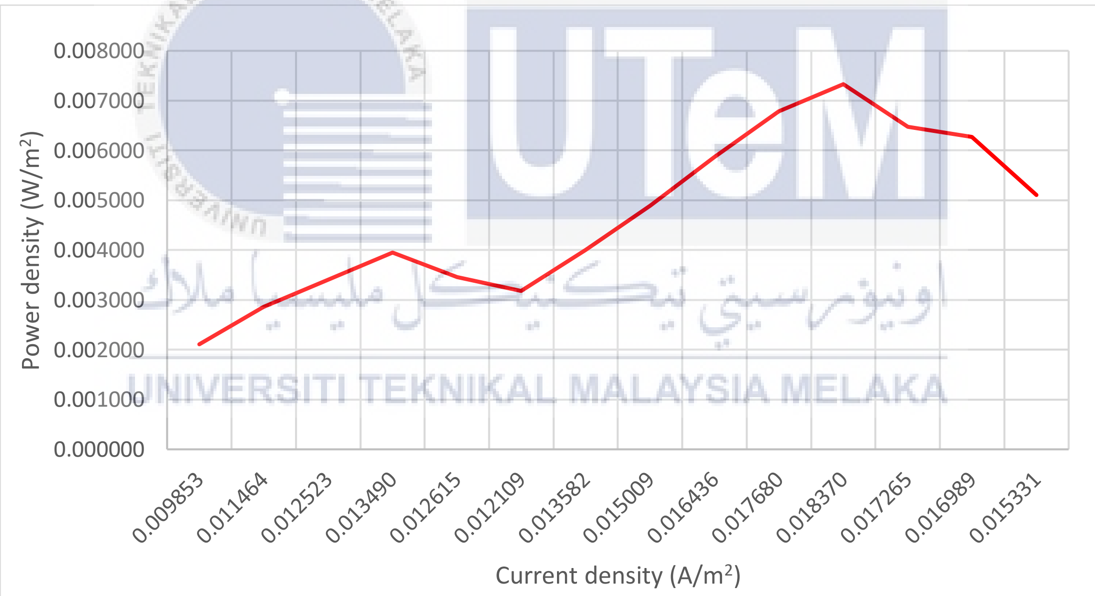


Figure 4.7 Power Density vs Current Density for Big Size Electrode

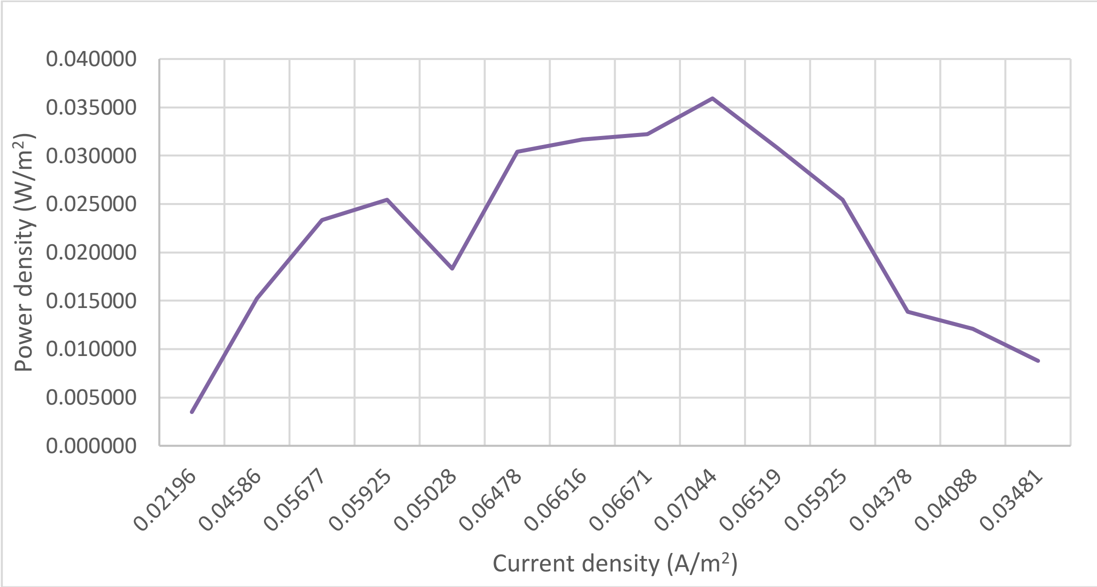


Figure 4.8 Power Density vs Current Density for Small Size Electrode with Spaces

Table 4.4 Average value for result obtained for different size of electrodes

Experiment	**Voltage (V)**	**Current (I)**	**Current Density (mA/m^2)**	**Power Density (mW/m^2)**
Small	0.2816	0.00282	19.03	5.48
Big	0.3145	0.00315	14.48	4.69
Small with spaces	0.3859	0.00386	53.30	21.92

Table 4.4 shows the data average of the voltage, current, current density and power density produce by different electrode size used in the experiment which is small, big and small size with spaces. From Figures 4.6, 4.7 and 4.8, the higher rate of voltage, current density and power density produce in MFC is when small size of electrode with spaces is used. The distance between the electrode included with spaces can fulfill the whole chamber while the whole electrode has been used for diffusion of ions. Hence, the observation shows that although the electrode is has small surface area, but with spaces it can gives a better performance than bigger size.

4.3.3 Experiment C

In this section, the results of the experiment C which it is tested on the effect of electrode positioning are plotted in Figure 4.9 to show the comparison result of electrode position used which is horizontal and vertical position. For this experiment, the type of food waste used is apple for all the electrodes size due to the best food waste energy production and the electrode used is small in size with spaces due to best electrode size for energy production. This experiment is conducted using the best results of type of food waste and electrode size used from the previous experiment in attempt to increase the power generation of MFC.

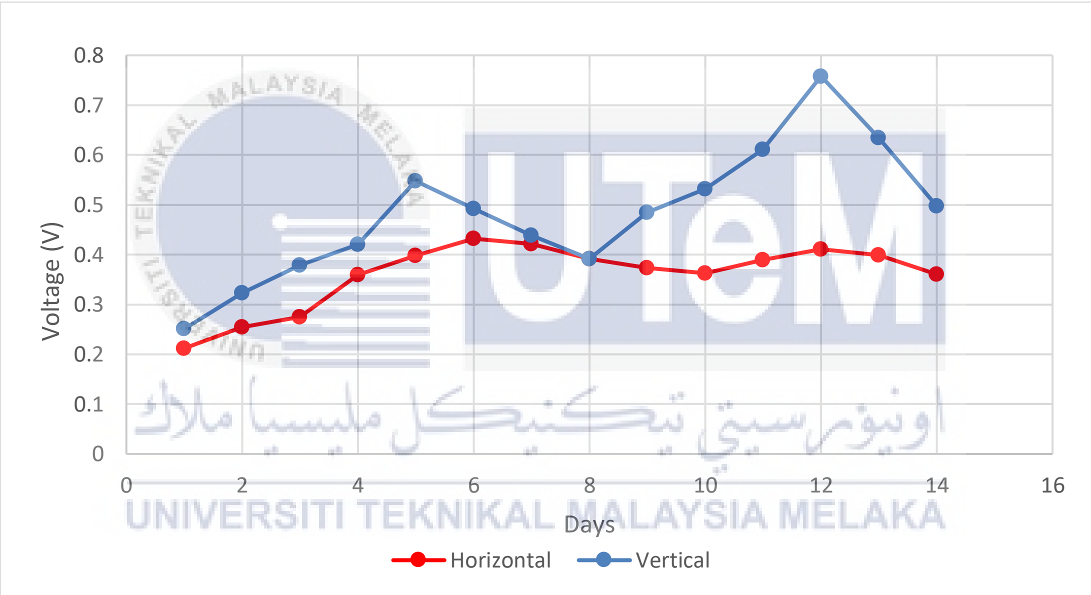


Figure 4.9 Comparison of Voltage Produce Per Day by Horizontal and Vertical Position

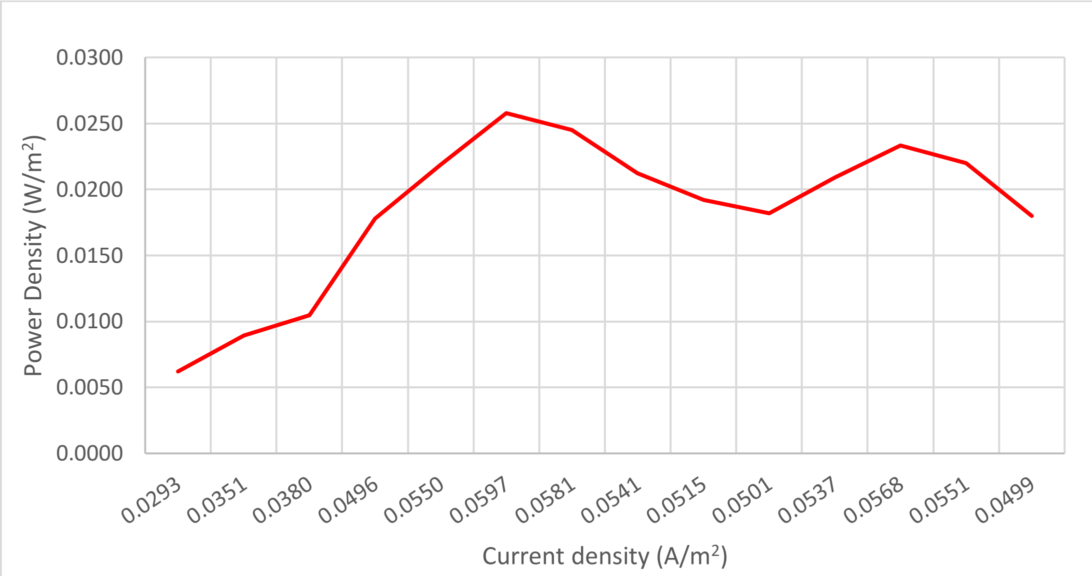


Figure 4.10 Power Density vs Current Density for Horizontal Electrode Position

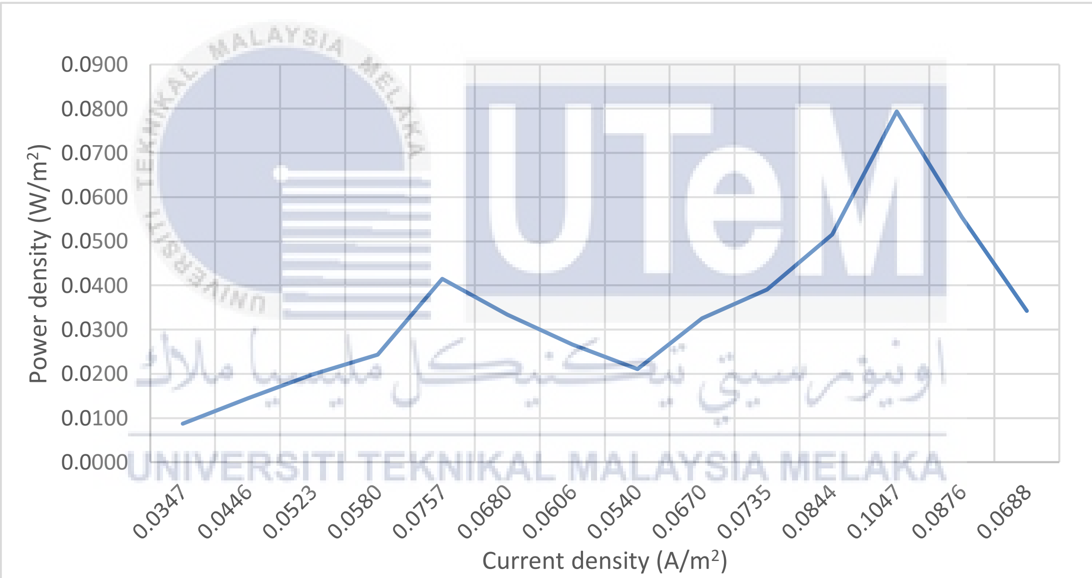


Figure 4.11 Power Density vs Current Density for Vertical Electrode Position

Table 4.5 Average result obtained for Electrode Positioning

Experiment	**Voltage (V)**	**Current (I)**	**Current Density (mA/m^2)**	**Power Density (mW/m^2)**
Horizontal	0.3599	0.0036	49.714	18.455
Vertical	0.4829	0.00483	66.70	34.446

Table 4.5 shows the data average of the voltage, current, current density and power density produce by different electrode position used in the experiment which is horizontal and vertical. From Figure 4.10 and Figure 4.11, the higher rate of voltage, current density and power density produce in MFC is when vertical position of electrode is used. This may be cause from the diffusional resistance and accumulation of ions around electrode in the vertical configuration. Since different positions in the reactor had different substrate diffusion rate which also acts as limiting factor. Therefore, different position in the reactor gives impact to the energy generations.

4.4 Summary

This chapter provided the result for this project study. The data that has been obtained in this project is used only to determine either the MFC can be used to generate electricity from food waste. Various ways can be implemented to increase the voltage output thus more experiment can be conducted to test the performance of the MFC.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project presented the development of energy from food waste using microbial fuel cell. There are three objectives that has been presented where the first objective was to develop an effective microbial fuel cell system using two chamber of food waste such as fermented apple, tomato and milk. To accomplish the first objective, a lot of research and study has been made to understand the concept of MFC and how to design it. Due to various research, the two chamber MFC has been created and develop thus can produce energy from food waste. Therefore, the first objective has been achieved where it can be concluded that using food waste for two chamber MFC system is possible.

The second objective is 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 position and different electrode size. For this objective, all of the parameters listed have been tested in this project. This objective has been achieved as the correlation of the power density have been identified for all parameters.

Lastly, the third objective is to analyze the best characteristic performance based on the proposed parameters test. With all the results obtained, it can be concluded that to get a better performance, it is best to combine the MFC with fruits that release sugar faster with a more acidic pH level and conduct it using small sizes electrode with spaces that been arranged in vertical position. Hence, the third objective for this project has been achieved as a conclusion of the best characteristic performance have been obtained for a better food waste for electricity production in microbial fuel cell.

5.2 Future Recommendation

This study showed that without harming the environment or reliable to the climate, a new renewable energy can be create thus creating save and free energy to mankind. But this kind of MFC is still not good to act as a generator itself as it produce a small amount of energy. More study and research need to be done to accomplish the goal and target for MFC as a renewable energy. With the new era of technology, MFC can fulfilled the energy demand of the world besides resolve the pollution and reduce the garbage of food waste in the world.

Thus, it can suggested that a bigger MFC or big surface area of the chamber can be created as the power density produced are depends on the total surface area of the electrode and the chamber. So, a future studies are suggested to for development of generating energy from food waste to reduce the use of non-renewable energy and accommodate the energy demand of the world.

REFERENCES

[1] Max Roser and Esteban Ortiz-Ospina. (2017, April). World Population Growth [Online]. Available: https://ourworldindata.org/world-population-growth

[2] David C. Hendrickson. (2011, March 22). World Population and Energy Demand Growth [Online]. Available: http://pictorial-guide-to-energy.blogspot.com/2011/03/world-population-and-energy-demand.html

[3] Vural Chantug Akkas. (2017, June 17). Malaysia Energy Profile: Strategically Located for Seaborne Energy Trade – Analysis [Online]. Available: https://vcantugakkas.wordpress.com/2017/06/16/malaysia-energy-profile-strategically-located-for-seaborne-energy-trade-analysis/

[4] Alternative Energy. What is Microbial Fuel Cells? [Online]. Available: http://www.altenergy.org/renewables/what-are-microbial-fuel-cells.html

[5] M. Rahimnejad, A. Adhami, S. Darvari, A. Zirepour, and S. E. Oh, "Microbial fuel cell as new technol ogy for bioelectricity generation: A review," Alexandria Eng. J., vol. 54, no. 3, pp. 745–756, 2015.

[6] Rinkesh. What is Renewable Energy? [Online]. Available: https://www.conserve-energy-future.com/advantages-and-disadvantages-of-renewable-energy.php

[7] Jack's Fresh Mart. (2018). Waste Composition in Malaysia [Online]. Available: http://www.jacksfreshmart.com.my/about-us/

[8] Abdul Qayyum Jumadi and Navshed Navin. (2013). Malaysia's Taste For Waste [Online]. Available: https://poskod.my/features/malaysias-taste-waste/

[9] A. Parkash, "Microbial Fuel Cells: A Source of Bioenergy," J. Microb. Biochem. Technol., vol. 8, no. 3, pp. 247–255, 2016.

[10] Anthropophobia. (2016, December 16). AS Chemistry – Redox Reactions and Group

2 Elements [Onine]. Available: https://owlcation.com/stem/AS-Chemistry-Group-2-and-7-Elements

[11] Alternative Energy. Microbial Fuel Cell Principles and Applications [Online]. Available: https://www.altenergymag.com/article/2009/12/microbial-fuel-cellsprinciples-and-applications/587

[12] M. Rahimnejad, A. Adhami, S. Darvari, A. Zirepour, and S. E. Oh, “Microbial fuel cell as new technol ogy for bioelectricity generation: A review,” Alexandria Eng. J., vol. 54, no. 3, pp. 745–756, 2015.

[13] M. Sun, L. F. Zhai, W. W. Li, and H. Q. Yu, “Harvest and utilization of chemical energy in wastes by microbial fuel cells,” Chem. Soc. Rev., vol. 45, no. 10, pp. 2847–2870, 2016.

[14] Colin S. Takeda, “Electricity from Garbage: Using a Microbial Fuel Cell to Create Energy from Food Waste,” p. 2013, 2013.

[15] Z. He, Y. Huang, A. K. Manohar, and F. Mansfeld, “Effect of electrolyte pH on the rate of the anodic and cathodic reactions in an air-cathode microbial fuel cell,” Bioelectrochemistry, vol. 74, no. 1, pp. 78–82, 2008.

[16] S. Puig, M. Serra, M. Coma, M. Cabré, M. D. Balaguer, and J. Colprim, “Effect of pH on nutrient dynamics and electricity production using microbial fuel cells,” Bioresour. Technol., vol. 101, no. 24, pp. 9594–9599, 2010.

[17] M. Sun, L. F. Zhai, W. W. Li, and H. Q. Yu, “Harvest and utilization of chemical energy in wastes by microbial fuel cells,” Chem. Soc. Rev., vol. 45, no. 10, pp. 2847–2870, 2016.

[18] V. Lanas, Y. Ahn, and B. E. Logan, “Effects of carbon brush anode size and loading on microbial fuel cell performance in batch and continuous mode,” *J. Power Sources*, vol. 247, pp. 228–234, 2014.

[19] A. Parkash, “Microbial Fuel Cells: A Source of Bioenergy,” *J. Microb. Biochem. Technol.*, vol. 8, no. 3, pp. 247–255, 2016.

[20] P. Pushkar, O. Prakash, A. A. Mungray, K. S. Kumar, S. Chongdar, and A. K. Mungray, “Evaluation of the Effect of Position and Configuration of Electrodes in Benthic Microbial Fuel Cell,” no. 0, pp. 1–9, 2018.