DRY FERMENTATION TO PRODUCE BIOGAS

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DRY FERMENTATION TO PRODUCE BIOGAS

NURAINI ATIKAH BINTI MOHAMMAD

Thesis submitted in fulfilment of the requirements
for the award of the degree of
Bachelor of Engineering Technology in Manufacturing

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of degree of Bachelor of Engineering Technology in Manufacturing.

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ABSTRACT

The rising of population size in Malaysia has definitely causing the usage of energy also increasing. In numbers, according to the National Energy Balance, 2008, Malaysia has stated a rise in basic energy usage at rate of 6.1 % per year between 2000 until 2008. This value also is getting nearer to the average annual increase in GDP in 6% in the same period. Thus, green technology is introduced to help in reducing the energy usage. Green technology can exist in form of energy, which includes the development of alternative fuels and that means new efficient energy can be generated. Some of industrial sector in Malaysia also have transforming their energy source into this alternative energy. One of the new sources of alternative energy is the bioenergy. Bioenergy which comes from bioethanol, biodiesel, and biogas has seen to become a good alternative and in this project, biogas is the source of energy that going to be produce. Biogas is an energy sources that can be produced from either wet fermentation or dry fermentation through anaerobic digestion process. Dry fermentation has become the main highlight in this project as it used minimal water supply, smaller reactor , and does not use any stirrer during the ongoing process thus less energy is used. Few reactors needed to be built so that the fermentation process can take place in it. Through this dry fermentation, anaerobic digestion will occur where the organic material is broken by the microorganisms and resulting the biogas being released. Content of the biogas will be analyse and measure by using the water displacement method. The biogas later can be used as an alternative to heat and electricity generation and natural gas substitute. This paper will focus on different type of reactor design on the movement of microorganism to react with biomass and start anaerobic process to produce biogas. Arrangement of organic material in the reactor itself and the hydraulic retention time also will be studied further. This paper also will discuss on designs and fabrication of a dry fermenter and to study the fermenter performance.

ABSTRAK

Peningkatan saiz penduduk di Malaysia pasti menyebabkan penggunaan tenaga juga meningkat. Mengikut angka, mengikut Nisbah Tenaga Nasional, 2008, Malaysia telah menyatakan kenaikan penggunaan tenaga asas pada kadar 6.1% setahun antara tahun 2000 hingga 2008. Nilai ini semakin dekat dengan kenaikan tahunan purata KDNK pada 6% dalam tempoh yang sama. Oleh itu, teknologi hijau diperkenalkan untuk membantu dalam mengurangkan penggunaan tenaga. Teknologi hijau boleh wujud dalam bentuk tenaga, yang termasuk pembangunan bahan api alternatif dan ini bermakna tenaga yang cekap baru dapat dihasilkan. Sesetengah sektor perindustrian di Malaysia juga telah mengubah sumber tenaga mereka ke dalam tenaga alternatif ini. Salah satu sumber tenaga alternatif baru ialah bioenergi. Bioenergi yang berasal dari bioethanol, biodiesel, dan biogas telah dilihat sebagai alternatif yang baik dan dalam projek ini, biogas adalah sumber tenaga yang akan dihasilkan. Biogas adalah sumber tenaga yang boleh dihasilkan daripada penapaian basah atau penapaian kering melalui proses pencernaan anaerob. Penapaian kering telah menjadi tumpuan utama dalam projek ini kerana ia menggunakan bekalan air minimum, reaktor yang lebih kecil, dan tidak menggunakan pengaduk selama proses yang sedang berjalan sehingga kurang tenaga digunakan. Beberapa reaktor perlu dibina supaya proses penapaian dapat berlaku di dalamnya. Melalui penapaian kering ini, pencernaan anaerobik akan berlaku di mana bahan organik dipecahkan oleh mikroorganisma dan menyebabkan biogas dibebaskan. Kandungan biogas akan menganalisis dan mengukur dengan menggunakan kaedah anjakan air. Biogas kemudiannya boleh digunakan sebagai alternatif kepada penjanaan haba dan elektrik dan pengganti gas asli. Maka ini akan memberi tumpuan kepada jenis reka bentuk reaktor yang berlainan dalam pergerakan mikroorganisma untuk bertindak balas dengan biomas dan memulakan proses anaerobik untuk menghasilkan biogas. Pengaturan bahan organik dalam reaktor itu sendiri dan masa pengekalan hidraulik juga akan dikaji selanjutnya. Kertas ini juga akan membincangkan mengenai reka bentuk dan fabrikasi fermenter kering dan untuk mengkaji prestasi fermenter.

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LIST OF ABBREVIATION

MSW	Municipal Solid Waste
GC	Gas Chromatography
TCD	Thermal conductivity detector
MW	Mega Watt
FID	Flame Ionization Detector
AE	Anaerobic Digestion

CHAPTER 1

INTRODUCTION

Malaysia generally has a lot of natural gas reserves in the ocean and it belongs in top ten among liquid natural gas exporter in the world. Malaysia also used to be the biggest liquid natural gas exporter in the world in 2007 and now Qatar has taken the lead as the world biggest liquid natural gas exporter [1]. However, Malaysia also is included in the list of main world countries that has imported coal for energy generation purposes. According to Minister of Energy, Water and Communications Datuk Seri Dr Lim Keng Yai at 2020, the uses of coal in Malaysia is expected to rise from 20.4 million ton compared to 37 million tons in 2013 [2]. Indonesia become the world largest producer for coal with 60%, followed by Australia with 17% and 12% from South Africa [3]. Then, since 2013, Malaysia started to import coal from Russia for diversity purpose and still finding other suppliers as the demand for usage is increasing. This however has caused the carbon released in Malaysia has reached 8.0 ton per capita according to the latest record from the World Data Bank in 2013[4].

Thus, renewable energy has been introduced in Malaysia as it only left with 33 years of natural gas reserves and 19 years of oil reserves as the demand is increasing. Due to this, the Malaysian government is expanding into renewable energy sources [5]. Malaysian government now is seeking alternatives to intensify the development of renewable energy, particularly biomass, as the 'fifth fuel' resource under the country's Fuel Diversification Policy. This policy which has started back in 2001, had a target of renewable energy providing 5% of electricity generation by 2005, equal to 500 to 600 megawatt (MW) of installed capacity [6]. Renewable energy such as solar, wind, hydro, wave and bioenergy has high potential to support the existing energy sources and at the same time could reduce the environmental impact to the environment.

Bioenergy which can be derived from bioethanol, biodiesel and biogas has been seen to be a good alternative to Malaysia. Alternative to power generation, the produced biogas can be processed in to biomethane. This can then be fed into the natural gas grid or used as vehicle fuel (compressed natural gas). The generated energy can be stored and used in wider market [7]. Biogas is an energy source that can be produced either from wet fermentation or dry fermentation. There has been some comparison between dry fermentation and wet fermentation. In dry fermentation, the organic input remains stationary throughout the process, eliminating moving parts and resulting in low system maintenance and repair costs. There is also no pretreatment or sorting of inputs required prior to system loading thus it could save time and money for system operators [8]. Another benefit of using dry fermentation is that the organic input volume reduced by minimum of 40% which is a significant additional cost benefit and the waste water is eliminated thus removing risk of groundwater contamination. As for wet fermentation, its own system requires mechanical parts to circulate biomass in holding tank which then leads to increased maintenance and repair costs. This kind of system also requires additional liquid to allow fermentation. This means amount of waste water will increase and post process treatments will be costly. Another disadvantages of wet fermentation are the inputs require pre-treatment to prevent the breakdown of mechanical parts as input is agitated and moved through system and the liquid mixture causes premature removal of input before all organic matter has been digested thus causing in loss of energy [9]. Therefore, prior to these reasons, dry fermentation was given main exposure to be studied as it brings a lot benefits not only to the environment but is it also very affordable in terms of pricing.

This paper aims to focus on implementation of dry fermentation in anaerobic environment so that end product of biogas (methane) can be produced. The main idea is use food waste and sludge as the source of bacteria generation without any pretreatment or sorting of inputs and addition of water. Thus, the fermentation process occurs in dry condition since no water added. Dry fermentation is much more preferred compared to wet fermentation is because it is well suited to process organic food waste, integrates well into composting operations and virtually immune to physical contaminants as the input material remains stationary and does not come into contact with any moving equipment inside fermentation chambers [10].

As mentioned earlier, the end product is biogas (methane). Thus, an investigation will be performed to study the performance of reactor itself by measuring the amount of biogas produced through a certain method. This study also will emphasize on the characteristics of reactor and the factors that influence the quantity and quality of biogas production such as manure quality, temperature, retention time, composition, total solids and hydraulic retention time [11]. Besides that, this study also will investigate the on how different arrangement of manure and sludge inside the reactor could affect the hydraulic retention time. Furthermore, the study covers the process on designing the reactor itself using a 3D designing software called NX 10 Siemens that consist of the frame to place the reactor and the reactor bottles itself and the gasbag to store the collected gas. At the end of the study, the gas collected are expected to be fully methane composition as through fermentation process, other byproduct also may be produced such as carbon dioxide gas and many more.

1.1 Problem Statement

Biological material such as grasses, agriculture crops and trees can become source for lignocellulosic biomass. Rather than use source that human use in their daily live, waste such as Municipal Solid Waste (MSW) and industrial waste can be used for fermentation process to produce biogas. Previous technology in industry especially in dry fermentation process bring a lot of benefits to the industry as it not required any internal moving part where the waste will remain stationary. Less liquid feedstock or water needed to conduct the process thus contribute to less cost for the operation. As it has a lot of benefits against wet fermentation, it also has some limitation and challenges that need to overcome.

Dry fermentation will have longer hydraulic retention time as it has no moving part that will mixed the waste continuously with microorganism such as bacteria or yeast. Due to its longer time, this process will face problem from inhibitory compound that probably affect the final product of this process. As there are three stages of temperature that is ambient temperature, mesophilic temperature and thermophilic temperature, dry fermentation process can be carry out only at mesophilic temperature at range of 35-37 ℃ and thermophilic temperature at range of 50-60 ℃ [12]. Too low in temperature can lead to lower end product production and less efficiency. Another aspect that becomes a barrier while conducting this study is the matter of leakage and safety issue as the expected end product is methane and it is highly flammable. Methane can form mixtures with air that are explosive at concentrations of 5% to 15%. Methane is not toxic, but it can cause death due to asphyxiation by displacing oxygen in confined environments or spaces [13].

1.2 Objectives

This project has objectives as below:

1) To design a dry fermentation reactor.

2) To fabricate a dry fermentation reactor.
3) To study the fermenter performance.

1.3 Project scope

This study will focus on different arrangement of manure and sludge in the reactor could give an impact on the movement of microorganism to react with biomass and start anaerobic process to produce biogas. Following are the scope or limit of the study:

a) To design a dry fermentation reactor that can hold the amount of biomass and sludge within 2000 mL in reactor capacity.
b) To install the reactor bottle in series position included with proper monitoring system and safety proven.
c) To know the reactor efficiency by measuring the value of methane and to ensure the end product is purely methane gas instead of contaminated with other gas content at the end of study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Fossil fuels has been existed in our world since 650 million years ago and it can be found in the Earth's crust [15]. Example of fossil fuels are coals, petroleum and natural gases. Other commonly used derivatives include kerosene and propane. Fossil fuels range from volatile materials with low carbon to hydrogen ratios like methane, to liquids like petroleum, to nonvolatile materials composed of almost pure carbon, like anthracite coal [15]. A fossil fuel is a fuel formed by natural processes, such as anaerobic decomposition of buried dead organisms, containing energy originating in ancient photosynthesis [14]. However, fossil fuels are considered to be non-renewable as they are being formed through natural processes and it consumes such a long time to build its content [16]. Meanwhile, fossil fuels are consumed a lot of time and the rate are increasing as big companies keep on drilling them out for their own interest. Thus, depletion of fossil fuels used to create natural gases are increasing and more energy derived from other sources natural sources like coals are used to generate more energy to cover general demand.

Fig 1-3 show the three type of primary energy production in Malaysia. The production of petroleum is decreasing. The petroleum production reached its highest level of 8621.8 thousand barrel per day in 2004. However, this development could not be maintained on subsequent years, and production of petroleum entered into a regression period. Oil import is predicted to take place by 2013 and reach 45 Mtoe in 2030 [17]. Contrast to natural gas which is goes up in production. In 2008, the production of natural gas which is goes to 2023.55 billion cubic feet from only 56 billion cubic feet in 1980, Coal import will increase following governmental policy of intensifying its use for power generation [17]. As for coal, the consumption increased from 0.096 to 0.387 Quadrillion Btu from 2000 to 2008 [16] with the bulk of it consumed in power generation, mainly driven by the Malaysian governmental policy of shifting to coal in order to reduce high dependence of this sector to natural gas.

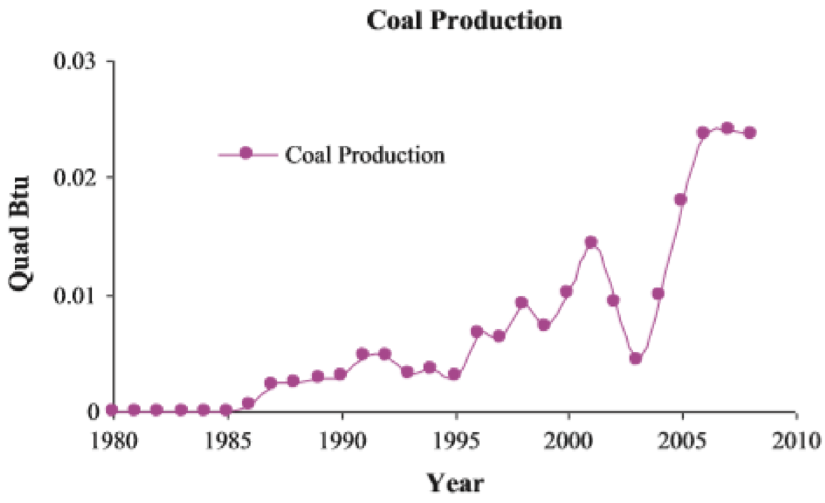

Fig.1 Coal production

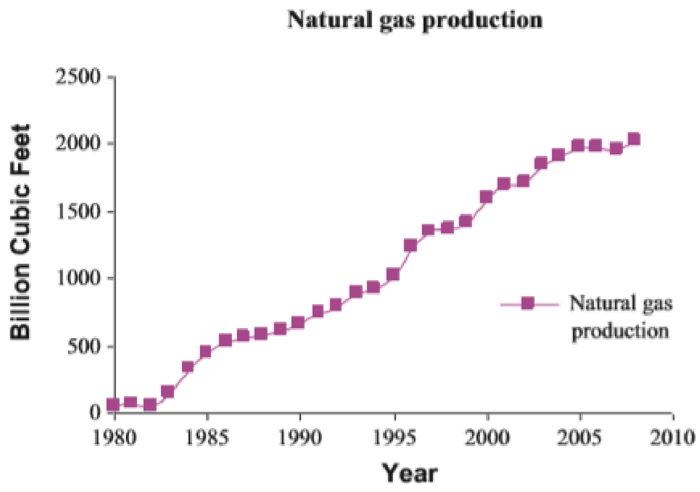

Fig.2 Natural gas production

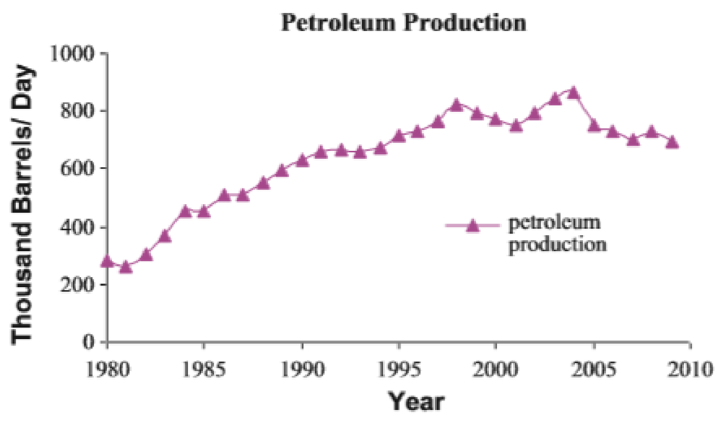

Fig.3 Petroleum production

2.2 Why methane ?

Methane can be found in hydrocarbon fields either alone, associated with oil, or in the form of methane clathrates [15]. It can also be derived from anaerobic digestion is competitive in efficiencies and costs to other biomass energy forms including heat, synthesis gases, and ethanol [18]. Compared to other fossil fuels, methane produces few atmospheric pollutants and generates less carbon dioxide per unit energy. Because methane is comparatively a clean fuel, the trend is toward its increased use for appliances, vehicles, industrial applications, and power generation. Methane can be used in a variety of stages of purity and efficiencies of transport and energy conversion are good compared to electricity [18].

2.3 Conversion process

Methane can be produced from biomass like oil palm cultivation, forestry(wood), rubber cultivation, animal farming and urban wastes. The process of producing methane can be furthered through either thermal gasification or biological gasification (commonly referred to as anaerobic digestion). Thermal processes for methane production also are economic at large scales and generate a mixture of gaseous products like hydrogen and carbon monoxide that must be upgraded to methane. However, thermal processes is limited to feeds with either a low water content (<50 %) or those having the potential to be mechanically dewatered inexpensively and this is due to energy needed for evaporation of water in order to energy needed for evaporation of water in order to achieve high temperatures required for the process. Feedstock containing 15% total solids require all of the feed energy for water removal. As for biological gasification or anaerobic digestion, it is a low temperature process that can convert wet or dry (with added water) feeds economically at a variety scales. The product gas is composed primarily of methane and carbon dioxide with traces of hydrogen sulphide and water vapor. The major limitation of biological gasification is that conversion is usually incomplete, often leaving as much as 50% of the organic matter uncovered. Process rates are significantly lower than those of thermal process and the bacteria involved require a balanced diet of nutrients that may not be available in some feedstock [18]. The two technologies from the perspective of energy efficiency were compared and the simulation results show that they have similar efficiencies : 62-64% for anaerobic digestion and 65% for GoBiGas [19].

2.4 Gas Measurement

The most common method adopted in researching the level of CO_2 and CH_4 is the monitoring of biogas production. Monitoring of gas production can give vital information about the state of the anaerobic degradation process. The comparison of biodegradability data from different scientific papers can be complex task. This is not only due to the difference in environmental conditions and protocols, but also due to the variety in equipment used. However, many researchers are improving the methods usability by developing automatically operated instruments according to the experimental requirements [20, 21].

Gas chromatography (GC) is an optimal analytical instrument for the analysis of components such as CH_4, CO_2, H_2S and siloxanes which are present in the gas [22]. The most important factors affecting the precision of biogas volume measurement and sensitivity are errors due to varying temperatures, vapor content, solubility and pressure [23]. The gas measurement technique and process itself can result in the inhibition of anaerobic digestion. The gas measurement technique and pressure itself can result in inhibition of anaerobic digestion. This is because the high amount of dissolved CO_2 can affect the pH of the medium and consequently can alter the microbial activity [24].

2.5 Gas Chromatography

Gas chromatography is a popular instrument and has several advantages such as high resolution, high speed, high sensitivity and good quantitative results. GC is an ideal method since it is well suited for the measurement of gas which is in contact with its liquid phase [25]. GC can simply help in determination of the ultimate methane potential of substances and their rate of biodegradation. The biogas process is commonly investigated at 35°C and to a lesser extent at 20°C, 55°C, and 70°C. However, the standard methane, that is used for comparison is prepared at the laboratory room temperature (20 to 23°C).

Anaerobic reaction undergoes different changes in gas pressure.

$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$	Hydrogenotrophic methanogenasis
$CH_3COOH \rightarrow CH_4 + CO_2$	Aceticlastic methanogenasis
$CH_3COOH + 2H_2O \rightarrow 4H_2 + 2\ CO_2$	Acetate oxidation
$4H_2 + CO_2 \rightarrow CH_3COOH + 2\ CO_2$	Homoacetogenesis

In hydrogenotrophic reaction, 5 mole of gas is converted into 1 mole of gas resulting in the decrease of pressure. On the other hand, the conversion of acetate into CO_2 and CH_4 will results in the rise of pressure. The pressure can vary from the type of substrate used and the products formed. In normal anaerobic $H_2 + CO_2$ culture, the pressure can vary from 0.6 to 2.5 atmp (1 atmp = 101.29 kPa) [19]. Samples are inserted into the GC after running the prepared calibration standards of CO_2 and CH_4. The thermal conductivity detector (TCD) is widely used for the detection of light hydrocarbons and compounds that responds weakly to the flame ionization detector (FID). The TCD is less sensitive than the FID. This is due to FID being very sensitive towards organic molecules. FID analysis is important when measurement required for small amounts of hydrocarbon as it can give larger signals and hence better precision than TCD [26].

2.6 Gasification via anaerobic fermentation

Biomass gasification or anaerobic digestion (AE) process normally produced biomethane which has its own characteristics. Anaerobic digestion is biochemical process, during which complex organic matter is decomposed of heat and electricity. Thus, it normally has a high energy efficiency [27]. Fig.4 shows how anaerobic digestion involves several different types of bacteria working together to break down complex organic material in stages to produce biogas. Step 1 is hydrolysis, which involves bacteria that can convert insoluble carbohydrates, proteins, and fats into simple sugars, fatty acids, amino acids, and peptides. Step 2 is a fermentation process where acid-forming bacteria, also known as acidogens, convert the products of hydrolysis into simple organic acids, alcohols, carbon dioxide, and hydrogen gas by acetogenic bacteria that only produce hydrogen. At step 3, methane forming bacteria (methanogens) produce biogas from acetic acid or hydrogen and carbon dioxide.

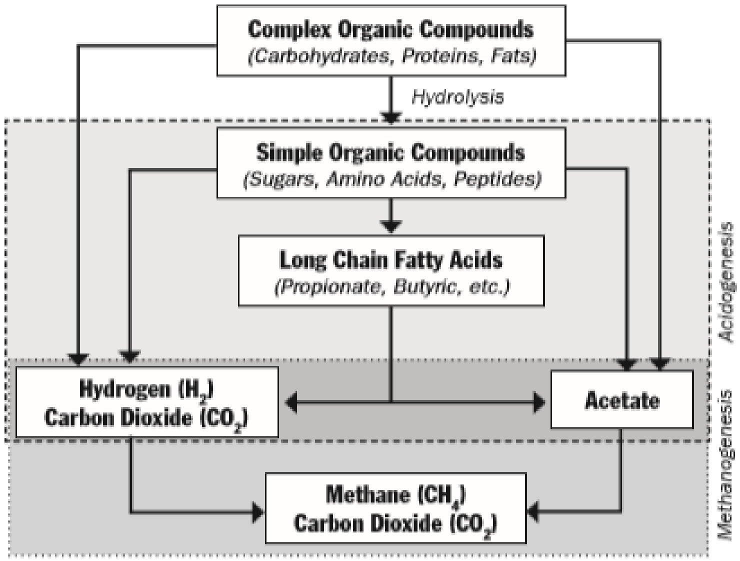

Fig.4 Steps involved in the breakdown of organic materials to produce biogas.

Although anaerobic digestion is a natural process, managing the reactor to obtain proper breakdown of organic matter and yield the maximum amount of biogas can be complex. The reactor requires careful management to maintain optimum temperature, water content, acidity (pH) and feedstock composition and volumes. Additionally, it is critical to address any toxic elements that may be inherent to a particular feedstock or that are produced through the anaerobic digestion process [28].

CHAPTER 3

METHODOLOGY

3.1 Fabrication of reactor

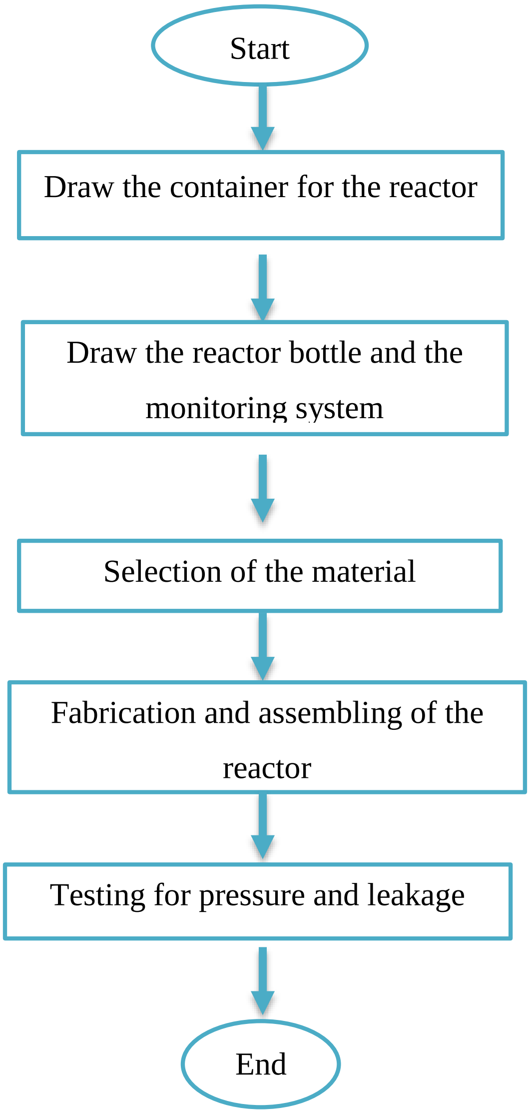

Fig.5 Flowchart that shows the fabrication of the reactor

Fig. 5 shows the process in fabricating the reactor. Fabrication of the dry fermentation reactor starts with the designing of the reactor. The reactor was designed by using a 3D designing software called NX Siemens 10 (Fig.6). First, the drawing process starts with the container. The container functions as to place the reactor bottle and the attachment of monitoring system on the front panel of the container wall. Then, the designing process was continued by drawing the reactor bottle and the monitoring system. The monitoring system was consisting of pressure gauge. Pressure gauge functions as to measure the pressure produced from the fermentation process inside the reactor. Another component of the reactor is pressure valve. Pressure valve functions as to control the amount of pressure that flow inside the pneumatic tube.

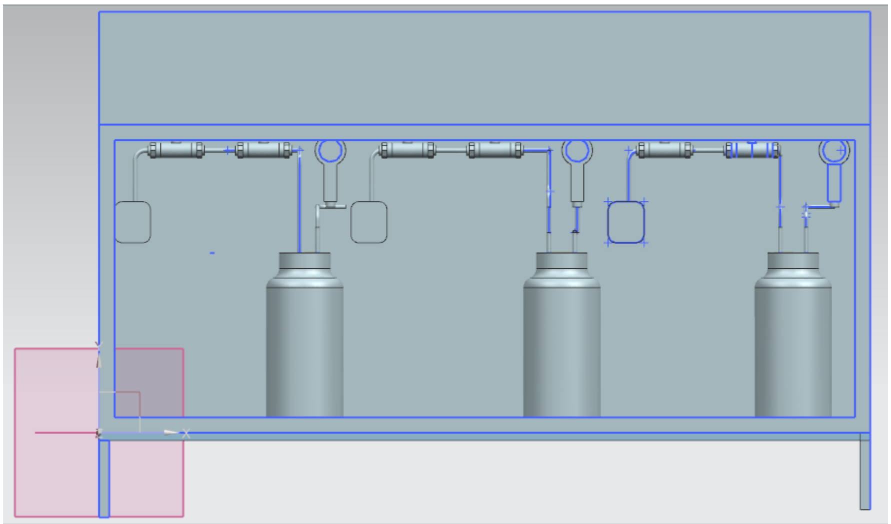

Fig. 6 Design of reactor by using NX Siemens 10

Selection of material in making this reactor has been considered carefully as it could affect the fermentation process. Mild steel was used as the material for the reactor container (Fig.7). Mild steel is one of the most common of all metals and one of the least expensive steels used. It is to be found in almost every product created from metal. Mild steel also is weldable, very durable, relatively hard and is easily annealed [29]. As for the reactor bottle, Schott Duran laboratory glass type of bottle was used (Fig.8). This is because, since the fermentation process will produce biogas with pressure thus the bottle that was used must able to resist high pressure from surrounding. Furthermore, the Schott bottle able to withstand pressure up to 1.5 bar [30]. Pneumatic brass ball valve was used as to control the pressure that flow from the reactor bottle. Type of pressure gauge that was used in this project is Bourdon pressure gauge (Fig.9). The Bourdon tube pressure gauge is available for the pressure range up to 25 bar. The Bourdon tubes are circular curved tubes with an oval cross section. When air pressure is applied to the inside of the Bourdon tube, its cross section changes and becomes more circular. The resulting tensions bend open the spring. The unclamped end of the spring reacts to the amount of pressure. A mechanical system picks up and indicates this movement. The circular springs, which are curved at an angle of approx. 250°, are used for pressures of up to 60 bar. Bourdon tubes are only protected against overload to a certain point [31].

Fig.7 Mild Steel

Fig. 8 Schott bottle 2000 mL

Fig. 9 Bourdon pressure gauge

Fabrication of the reactor starts by cutting the hollow section steel that were used in making the reactor and it acts as support for the frame of the container. The hollow section steel was cut by using Bosch sliding miter saw. The hollow steel then is being welded together to form joint and frame(Fig.10-13). The welded frame then was spray paint with black colour to prevent it from rusting. Mild steel was used as wall for the container and then was attached to the welded frame by using a hand riveter. After that, a clear Perspex was cut to form a window so that the any changes in reactor bottle can be monitored from outside. Then, the pressure gauge and pneumatic pressure ball valve were installed at the back panel of the reactor. Two holes were drilled at the upper part of the cap and pneumatic fitting was attached through it. The pneumatic tube then was attached to the pneumatic fitting. In this project, all connection is done in pneumatic type as it can hold more air in it and can withstand high pressure besides to prevent any leakage. Pneumatic tube also was used to connect the reactor bottle to the pressure gauge and pressure valve. This reactor was designed to have three stations as each station has different arrangement and condition of food waste and sludge inside the reactor. The arrangement of food waste and sludge in first reactor were done layer by layer. At the second bottle, the sludge was put on top of the food waste. Third bottle acts as control sample.

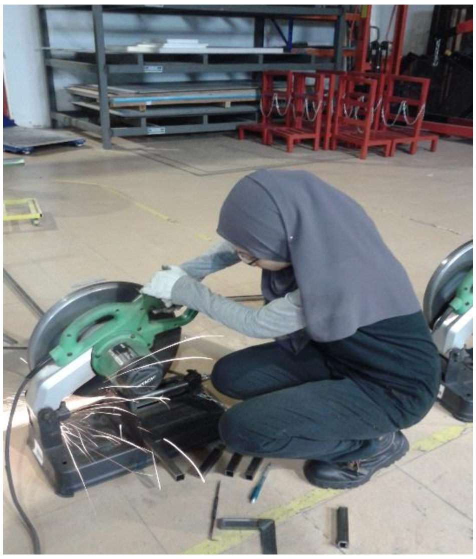

Fig.10 The hollow section steel was cut by using miter saw

Fig.11 The hollow section steel was welded together to form a frame for making container

Fig.12 Welded frame for reactor container

Fig.13 Dry fermentation reactor

Next step in this project is testing for pressure and leakage. The construction of the reactor has been done in a way to ensure it is safety proven. This is due to properties of methane itself and the pressure occurred from the fermentation process inside the reactor. The primary methane gas hazards are its flammability, its explosive potential, and the possibility of asphyxiation. Mixtures of about 5% to 15% methane in air make an explosive mixture. Asphyxiation can be caused by breathing air with a high concentration of methane, because the high concentration of methane can reduce the oxygen level below that which is needed for life [32]. Thus, the testing need to be done to know the maximum pressure the reactor bottle can handle and to prevent the reactor from explodes besides to contain it from air leakage. The cap of the bottle was attached with rubber and washer and glued with super glue to prevent it from air leakage (Fig.14). Soap water was poured on top of the reactor bottle cap and air was supplied into the reactor bottle from air compressor. If the bottle releasing bubbles, it indicates there is air leakage. So this is very dangerous as it could release the final product of fermentation, biogas and no product can be collected.

Fig.14 The bottle cap was attached with rubber to prevent air leakage

3.2 Substrate and inoculum

The journey in conducting the fermentation process in dry anaerobic condition is then continued with the food waste and sludge source. The food waste which consist of vegetable, chicken, and fish was collected from nearby market and university cafeteria and used as feedstock for dry fermentation process. While the sources of bacteria come from anaerobic sludge collected from palm oil industry at Gambang, Pahang and used as inoculum. The temperature and pH of the sludge during collecting was 30℃ and 6.04 respectively with ambient temperature of 24℃ -29℃. The food waste was chopping into small size to increase the surface area and expose toward the microorganism. The pH of the sludge was balance before used for the process at the range of 6.5-7.5 which is a suitable condition for anaerobic process. In this project, three different setup of reactor was performed based on different arrangement but same amount of content (Fig.15-16). The first reactor, reactor A was set up with 1.2 kg of food waste and 300 ml of sludge with the sludge was layered on top of the food waste. The second reactor, B was arranged layer by layer between the food waste and sludge with also 1.2 kg food waste and 300 ml sludge. The sludge was added layer by layer for every 200 g of food waste. The third reactor, C act as control with 1.5 kg of food waste. The anaerobic digestion process was setting up and monitored for a period of 25 days to identify the retention time for each of the reactor to produce a certain amount of biogas.

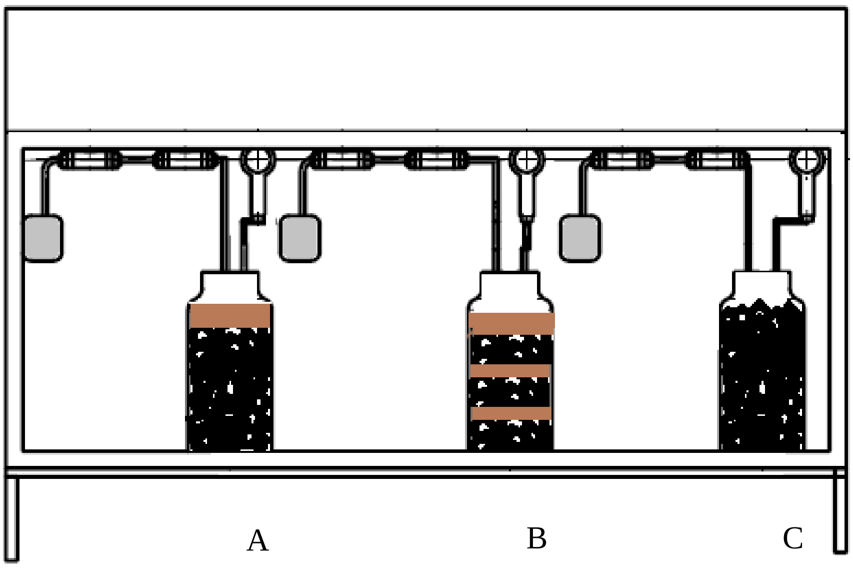

Fig.15 Schematic diagram shows different arrangement in each reactor

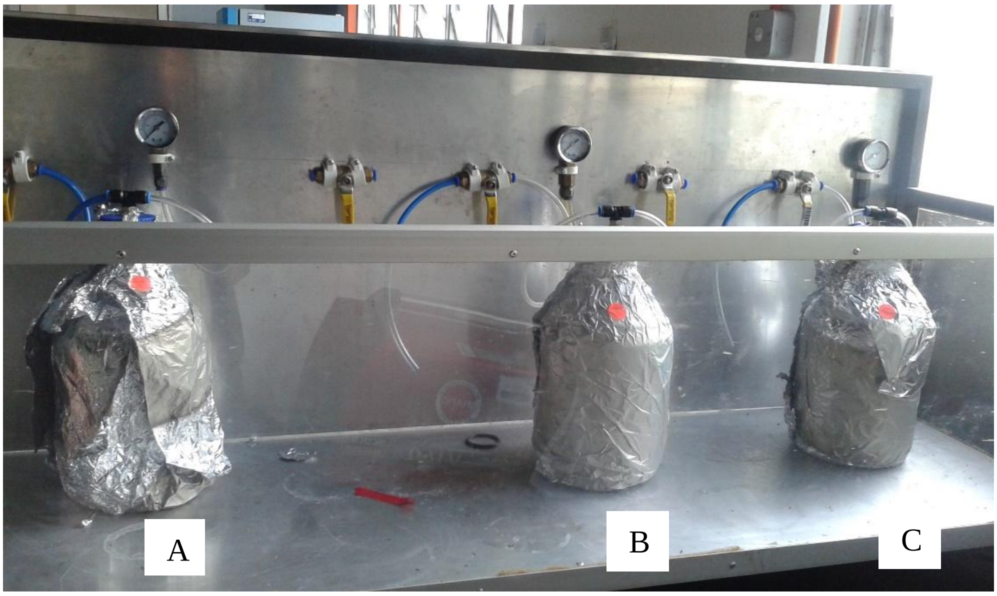

Fig.16 The reactor was left for 25 days

CHAPTER 4

COST ANALYSIS AND PROJECT MANAGEMENT

4.0 Cost Analysis

This chapter will emphasize on cost analysis regarding the whole project. This project has been finally support by Faculty of Engineering Technology (FTeK). Each student can spend up to RM1200 for the whole project. This project is being managed by two students and means RM2400 can be spend for the production of the project. Table below shows the list of project component including the price.

No.	Items	Quantity	Price
1	Gas Hose	5m	RM25.00
2	Hose Clamp	2	RM4.00
3	Brass Clamp Nipple	3	RM15.00
4	PVC PT Socket	3	RM1.50
5	Hose Clamp	2	RM2.00
6	PVC Ball Valve	1	RM4.00
7	Brass t Joint	1	RM5.00
8	Tank Connector	1	RM1.50
9	Hose	3m	RM2.70
		Total	**RM60.70**
10	1/4 " M/M Mini	6	RM72.00
11	6x2 Male Straight	12	RM38.64
		Total	RM110.65
12	1/4 " 6mm Water Filter Hose	3m	RM9.00
13	Star Reducing Bush	6	RM25.44
14	Star Socket	6	RM26.71
15	Star Tubing (Loose)	2	RM6.40
		Total	**RM58.55**
16	1/8 " NPT Air Compressor / Hydraulic pressure Gauge	3	RM53.91

17	1/8 “ NPT Air Compressor / Hydraulic pressure Gauge	5	RM89.85
18	Tube OD 6mm to 4mm Pneumatic Reduced Tee Union Push In Air Fitting	10	RM25.00
19	Tube 4mm 5/32 One Touch Inline Flow Control Valve Throttle Pneumatic	10	RM66.00
		Total	**RM234.76**
20	Duran Laboratory glass bottles 1000ml Lab Bottle	6	RM203.58
21	Straight Male Connector 6 mm Push In Pneumatic Fitting	10	RM17.00
		Total	**RM212.58**
22	PU Fitting 6mm socket	7	RM14.00
23	PU Tee Fitting	3	RM9.00
24	PU Hose 6MM	4m	RM10.00
		Total	**RM33.00**
25	PU Union Tee 6mm	7	RM35.00
26	PU Fitting Straight Male Connector 6mm	3	RM9.00
		Total	**RM46.65**
27	Korea PU Tube	3m	Total = RM8.40
28	Festo Male Tee	3	RM39.75
29	Star Reducing Bush (3/8 x 1/4)	3	RM15.90
30	Star Reducing Bush (1/8 x 1/8)	3	RM12.72
		Total	**RM66.32**
		Overall Amount	**RM807.61**

Table 1: Product cost analysis

4.1 Gantt Chart

Project Progress on Controlling Part	Month										
	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Title Selection And Review											
Research Methodology & Design Selection											
Draft Design Proposal											
Submission Of Proposal											
Proposal Presentation											
Item Purchasing											
Design Reactor											
Reactor Assembly											
Project Testing											
Report Preparation											
Submission Of Report											
Report Presentation											

CHAPTER 5

RESULT AND DISCUSSION

Data collection session have been performed in order to study the performance of reactor based on different arrangement of food waste and sludge inside the reactor. A few parameters have been measured in order to identify the effect of different arrangement of food waste and sludge inside the reactor towards production of gas. The gas content and composition was measured by using a gas chromatography (Agilent 6892 Series GC System).

Week	Pressure, P (Bar)		
	Reactor A	**Reactor B**	**Reactor C**
Week 1	0.09	0.15	0.34
Week 2	0.26	0.21	0.38
Week 3	0.31	0.22	0.40
Week 4	0.13	0.15	0.22

Table 3: Pressure of reactors for week 1, 2, 3 and 4

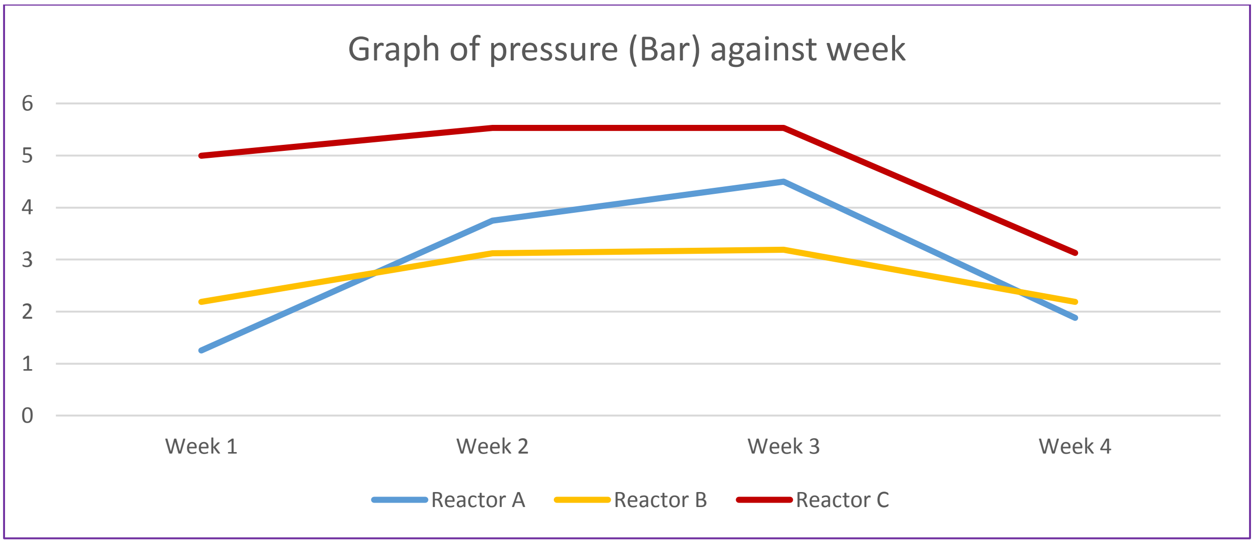

Fig. 17: Graph of pressure against week

Based on this graph, it shows the pressure of each reactor during week 1, 2, 3 and 4. From week to week, it shows that there is a fluctuation between the pressure because it take some time for the condition inside the reactor to become stable and producing the gas. By referring to the above graph, there was a rapid increasing in the pressure value for reactor C followed by reactor B and the slowest increase in pressure that is reactor A.

Gas	**Biogas composition (% volume)**			
	Week 1	**Week 2**	**Week 3**	**Week 4**
H_2	2.3	3.2	3.38	3.55
CO2	76.7	79.39	88.29	88.42
Total	79	82.59	91.67	91.97

Table 4: Biogas composition for Reactor A

Gas	**Biogas composition (% volume)**			
	Week 1	**Week 2**	**Week 3**	**Week 4**
H_2	3.01	3.44	4.27	4.94
CO2	77.67	80.19	88.94	89.22
Total	80.68	83.63	93.21	94.16

Table 5: Biogas composition for Reactor B

Gas	**Biogas composition (% volume)**			
	Week 1	**Week 2**	**Week 3**	**Week 4**
H_2	3.22	3.94	6.41	6.63
CO2	79.39	82.09	89.46	89.97
Total	82.61	86.03	95.87	96.60

Table 6: Biogas composition for Reactor C

The table above shows the biogas composition of the process in percentage volume from week 1 until week 4 for the three reactor. From the result, it shows that reactor C has the highest total biogas composition for week 1, 2 3 and 4 that is 82.61%, 86.03%, 95.87% and 96.60% respectively compared to reactor B and A.

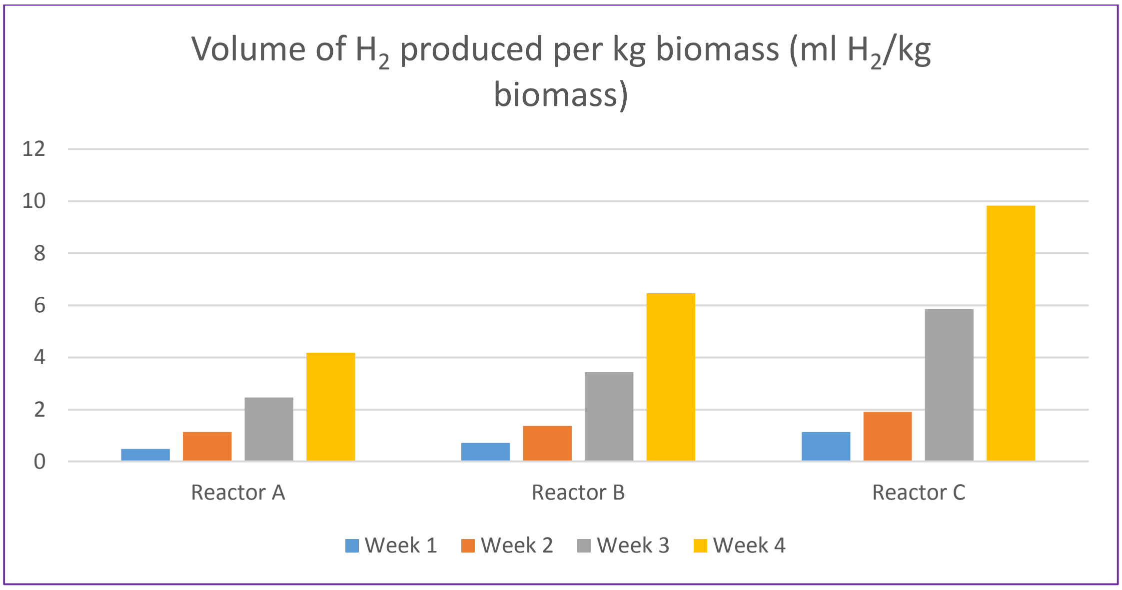

Fig. 18: Graph volume of hydrogen gas produced per kg of biomass

Based on the graph, it shows that all three reactors show an increase in amount on hydrogen gas (H_2) from week 1 to week 4. Therefore, we can say that the biomass inside the reactor react with microorganism from the inoculum and start producing the hydrogen gas. It can be seen that the reactor C produce the highest amount of hydrogen gas for each week. From 1 kg of biomass, the volume of hydrogen gas produced from reactor C from week 1, 2 3 and 4 are 3.22%, 3.94%, 6.41% and 6.63% respectively.

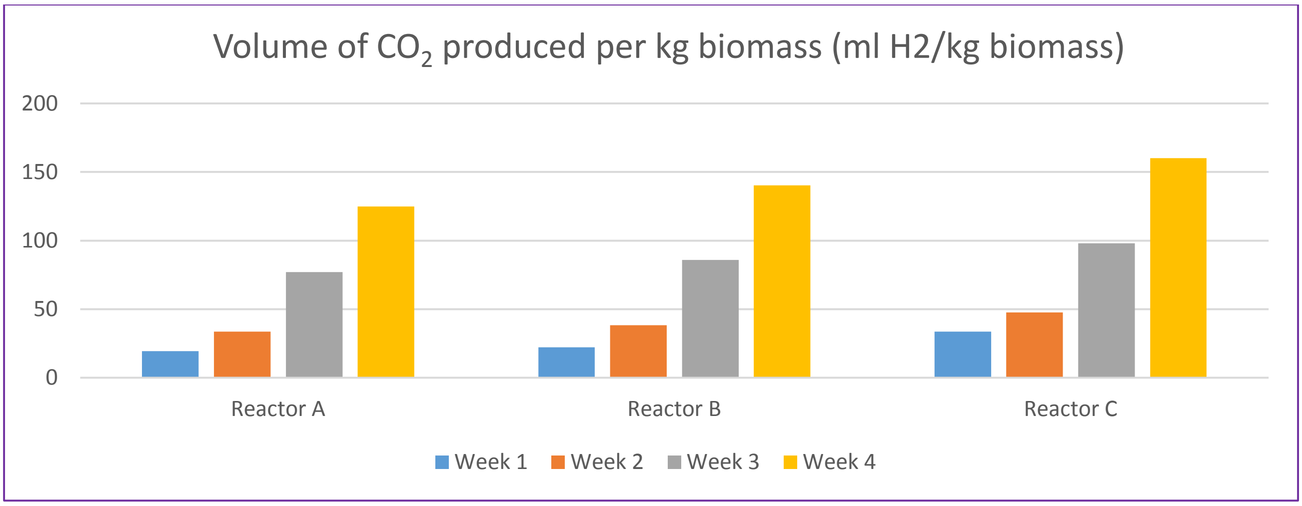

Fig. 19: Graph volume of carbon dioxide produced per kg of biomass

The graph show volume of carbon dioxide (CO_2) produced per kg of biomass. From 1 kg of biomass, the highest amount of CO_2 produced are 79.39%, 82.09%, 89.46% and 89.97% for week 1,2,3 and 4 respectively which is from reactor C.

As mentioned before, the objectives in this project are to design and fabricate a dry fermenter and to test its performance by focusing on how different arrangement of food waste and sludge inside the reactor could affect the production of gas. Thus, all objectives were achieved. However, the fermentation process managed to produce only hydrogen and carbon dioxide gas instead of methane. This may be due to the absent of microbe that can enhance the production of gas in the fermentation process. In this study, the fermentation process was let to be happened naturally instead of adding other content in the fermenter. Other than that, it could be due to parameter such as temperature that also could affect the production of gas. In thus study, only pH was taken as parameter that can be manipulated meanwhile, temperature was ignored. Digester temperature can affect the production of gas due to the bacteria can form methane gas at temperature ranges of 4℃ to 75℃. In general, methane production increases with increasing temperature. The three temperature regimes used in anaerobic digesters are psychrophilic, mesophilic and thermophilic with optimum temperature ranges for the growth of methane forming bacteria of 5℃ to 25℃, 30℃ to 40℃ and 50℃ to 62℃ respectively. Different bacteria dominate at different temperatures. Imbalances between different bacteria may develop, causing methane production to be reduced and other gases to be given off. The bacteria give up heat from respiration as they work. However, this heat is usually not adequate to keep the liquid warm, and supplemental heat has to be added. Uniform temperature is desired throughout the digester and should be maintained to prevent localized zones of depressed temperature and undesired bacterial activity. Temperature fluctuations in the digester will affect the activity of the methane forming bacteria [22].

This study can be improved by taking few factors into consideration to increase the gas production and enhancing the gas content purification. For example, using a suitable microbe to interact with sludge, optimum temperature for production of microorganisms and manure quality. Loading rate also is one of the factors influencing biogas production from food waste. The ability of a digester to convert organic material into methane is related to its loading rate. Loading rate is commonly defined to its loading rate. Loading rate is commonly defined as the amount of volatile solids fed to the digester per day per unit volume of the digester. In general, materials with high volatile matter content produce more biogas if digested properly. As for toxicity, substances that inhibit microbial activity should be kept out of the digester. For example, digesters treating municipal wastewater have failed on occasion because of the presence of copper, zinc, chromium, and nickel. High concentrations of alkali metals like magnesium, calcium, sodium, and potassium can be toxic to anaerobic bacteria. The digestion of livestock waste containing high nitrogen to carbon ratios is more likely to result in toxic conditions for bacteria arising from the concentration of free ammonia [22].

CHAPTER 6

ETHICAL CONSIDERATIONS

In this chapter, ethical aspect will be discussed. The process of construction of each part of this project starting from fabricating the design and performing the experiment must be execute without neglecting the safety and ethical aspect. The purpose of following all of the safety regulation and rules are to prevent any casualties among people especially to the student and make sure the workplace is conducive for the students to do the work.

Body fabrication required a high concern for ethical and safety aspect. Before starting any work inside the workshop area, students need to follow a few regulations regarding the attire. For example, wearing the safety boot, glove and glasses are to minimize the effect to the student if any casualties are happen to during the work in progress especially during welding process. During welding, the students are required to wear boots, glove and mask to avoid the welding spark from contacting with eyes and any part of the body. Each product that has been fabricated also must undergo a testing or data collection session. This session also must be performed in safety workplace. For example, once the reactor has fabricated, it must be tested for air leakage. The testing process started by supplying air from air compressor into the reactor. Before that, the reactor bottle cap is poured with soap water. When the air being supplied into the reactor bottle and the reactor cap releasing some air bubbles around the pneumatic tube and pneumatic fitting, it means there is an air leakage. Each of the reactor bottle cap also have been added with washer to make it air-proof. Other factor that could affect safety aspect for this session is weather, attire, and a few environmental conditions. In order to prevent any accident or bad incident during the work, each factor mentioned above must be considered before any work was started.

CHAPTER 7

CONCLUSION

In this study, a dry fermenter was fabricated and the performance of the fermenter was studied. The anaerobic digestion process was setting up and monitor for a period of 28 days equivalent to 4 week of experiment to identify the retention time for each of the reactor to produce a certain amount of biogas. The result indicates that the retention time to obtain biogas producing at reactor C are the shorter and also show a rapid process. While reactor B show medium performance and reactor A shows the longest retention time for a fermentation to occur and producing biogas at slowest rate. As the reactor C show a rapid rate of biogas produced, it can be conclude that the arrangement inside the reactor which arrange layer by layer was successful to reduce the retention time and increase the surface area between substrate and inoculum thus improve the performance of the reactor. Moreover, the system re-uses food waste as substrate to produce biogas which lead to generation of bioenergy therefore it is considered as green energy system. The reactor also has economically benefits as it use no mechanical devices to generate the system and also low liquid content needed thus reduce the dependency on water supply. Therefore, it will lower the overall operation and maintenance cost to operate such system for industrial scale in the future and at the same time to reduce the dependency on conventional energy.

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