BIOGAS PRODUCTION FROM *BENINCASA HISPIDA* WASTE

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BIOGAS PRODUCTION FROM *BENINCASA HISPIDA* WASTE

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*Dedicated to my beloved parents, family and best friend.*

*Thank you for believing in me.*

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**BIOGAS PRODUCTION FROM *BENINCASA HISPIDA* WASTE**

## ABSTRACT

Biogas is the mixture of gaseous that generated from the decomposition of organic matter in the absence of oxygen. It consists of methane, carbon dioxide, hydrogen and traces level of other gases. Agricultural wastes where available abundantly in Malaysia serve as one of the potential carbon sources to be utilize to produce biogas.Various sources of agricultural wastes had been investigated their potential in producing biogas. This work will focus on the utilization of *Benincasa hispida* or also known as Kundur and its potential to produce biogas with cow dung slurry as inoculum. Characterization of Kundur wastes and cow dung slurry for TS, TVS, initial pH, COD and $NH_3$-N are studied. This work also focused on the determination of optimum composition of Kundur waste for the anaerobic digestion. The study was carry out in 2L digester at mesophilic temperature range with total solid concentration of 10% TS and inital pH of about 7. Percent composition of sample A(100wt % Kundur waste) , B(80 wt % Kundur waste:20 wt % Cow dung) , C(60 wt % Kundur waste:40 wt % Cow dung), D(50 wt % Kundur waste:50 wt % Cow dung) and E(40 wt % Kundur waste:60 wt % Cow dung) were used. Sample D shown the most suitable composition with the highest biogas yield of 2.34ml/gTS followed by sample C of 1.46ml/gTS, sample E of 1.16mg/gTS, sample B of 0.3ml/gTS while sample A shown no production of biogas. The different compositions of Kundur waste and cow dung in anaerobic digestion influenced the total biogas production. This lead to a new degree of information Kundur waste are suitable to be used as substrate for biogas generation with the addition of cow dung as inoculum.

**PENGHASILAN BIOGAS DARIPADA SISA BUANGAN *BENINCASA HISPIDA***

## ABSTRAK

Biogas adalah campuran gas yang dihasilkan daripada penguraian bahan organik dalam ketiadaan oksigen. Ia terdiri daripada gas metana, karbon dioksida, hidrogen dan gas-gas lain. Sisa pertanian di mana tersedia dengan banyaknya di Malaysia berkhidmat sebagai salah satu sumber karbon yang berpotensi untuk digunakan sebagai sumber untuk menghasilkan biogas. Pelbagai sumber daripada buangan industri pertanian telah dikaji potensi mereka dalam menghasilkan biogas. Kajian ini akan memfokuskan potensi terhadap penggunaan sisa *Benincasa hispida* ataupun lebih dikenali sebagai Kundur untuk penghasilan biogas bersama penggunaan tahi lembu sebagai sumber inokulum. Pencirian sisa Kundur untuk analisis TS, TVS, pH awal, COD dan NH3-N telah dikaji. Kajian ini juga tertumpu kepada penentuan komposisi sisa Kundur yang paling optimum untuk pencernaan anaerobik. Kajian telah dijalankan di dalam kelalang 2L pada suhu mesophilik dengan kepekatan jumlah pepejal 10% dan pH awal sekitar 7. Peratusan komposisi sampel A (100% sisa Kundur), B (80% sisa Kundur: 20% tahi lembu), C (60% sisa Kundur: 40% tahi lembu), D (50% sisa Kundur :50% tahi lembu) dan E (40% sisa Kundur: 60% tahi lembu) telah digunakan. Sampel D menunjukkan komposisi yang paling sesuai dengan hasil biogas tertinggi 2.34ml/gTS diikuti oleh sampel C 1.46ml/gTS, sampel E 1.16mg/gTS, sampel B 0.3ml/gTS dan sampel A menunjukkan tiada pengeluaran biogas. Penggunaan komposisi yang berbeza bagi sisa Kundur dan tahi lembu dalam pencernaan anaerobik dilihat mempengaruhi jumlah pengeluaran biogas. Ini menunjukkan bahawa sisa Kundur adalah sesuai untuk digunakan sebagai sumber sebagai penghasilan biogas dengan penambahan tahi lembu sebagai sumber inokulum.

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## LIST OF SYMBOLS

| | |
|---|---|
| % | Percentage |
| $g/VS^{-1}$ | Gram over volatile solid |
| kg | Kilogram |
| KW | Kilowatt |
| mg | Milligram |
| Mg/L | Milligram over liter |
| ml | Milliliter |
| ml/gTS | Milliliter over gram Total Solid |
| MW | Megawatt |
| $^{o}C$ | Degree Celsius |
| U.l/gm | Unit liter over gram |
| wt% | Weight percent |

## LIST OF ABBREVIATIONS

| | |
|---|---|
| AD | Anaerobic Digestion |
| CD | Cow Dung |
| $CH_4$ | Methane |
| $CO_2$ | Carbon Dioxide |
| COD | Chemical Oxygen Demand |
| EPA | Environment Protection Agency |
| $H_2$ | Hydrogen |
| $H_2S$ | Hydrogen Sulphide |
| HCl | Hydrochloric Acid |
| HRT | Hydraulic Retention Time |
| INQ | Index Nutritional Quality |
| K | Kundur |
| MHLG | Ministry of Housing and Local Government |
| MSW | Municipal Solid Waste |
| $N_2$ | Nitrogen |
| NaOH | Sodium Hydroxide |
| $NH_3$ | Ammonia |
| $NH_3$-N | Ammonia-Nitrate |
| TS | Total Solid |
| TVS | Total Volatile Solid |
| US | United State |
| VFA | Volatile Fatty Acid |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Waste is defined as the eliminated or discarded substance or materials or by-product from the completion of a process as they no longer useful. During the olden time, the wastes generated is low and bring less environmental effects occurs as the human population and the activities of industrialization is minimal. However, abundant of waste nowadays from various industry such as agricultural, forestry, municipal market waste, food processing industries, etc., constitute a large and serious environmental burden to the places all over the world. In Peninsular Malaysia, there was approximately 4.2 million tons of crop excesses including vegetables and fruits waste while there is around 2.3 million tons of livestock waste were produced (Lim, 1992). As for other country such as in India reported by Banu et al. (2007), production of fruits in India is estimated to be over 60 x $10^6$ tons annually and 40% portion of the fruits are lost as result from the inadequate transport, low storage qualities and marketing. Those wastes are disposed of in an uneconomical and less friendly ways which create a huge pollution problem in the country. This supported by Bouallagui et al. (2005) where other country such as Tunisia also constitute really huge amount of waste from fruit and vegetables and become the source of nuisance in municipal landfill and less effective disposal process.

In common practice in organic solid waste management from the agriculture sectors and livestock farm, the wastes commonly are transported to the landfill to be thrown away. Other than that, incineration is the other method where the process of combustion of the organic matter into ash takes place. However, as according to the Ministry of Housing and Local Government (MHLG), the majority of all 112 landfills in Malaysia are almost at its full capacity. On the other hand, incineration process releases odor emissions and bad for human health. Alternatively, there is one green way to converting the wastes into something valuable for human being which is anaerobic digestion. Anaerobic treatment encompasses of decomposition of organic material in the absence oxygen to produce gases such as methane, carbon dioxide, ammonia and traces of other gases and organic acids of low molecular weight (Abu Bakar and Ismail, 2012).

Fruits waste have much easily digestible carbohydrate and this represent the potential substrate or feed for production of biogas such as hydrogen ($H_2$), carbon dioxide ($CO_2$) and methane ($CH_4$) through anaerobic digestion (Zajic et al., 1979). In recent years, researchers have been attracted to study the anaerobic treatment of fruit wastes and other types of biomass as in Figure 1.1, to generate biogas such as $H_2$

and $CH_4$ because it involve treating the wastes into more stabilized form and generate useful products. Apart from that, this process not only provides renewable sources of energy that can be used as electricity or cooking but produce excellent organic manure (Mallick et al., 2009).

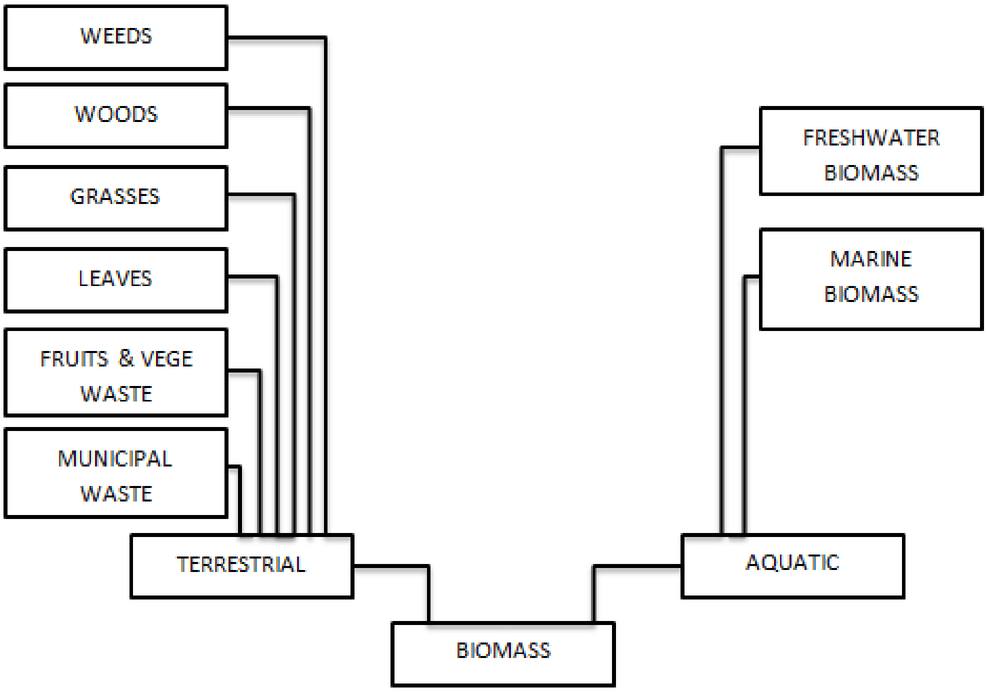


**Figure 1.1** Selected types of biogas yielding biomass (Source: Gunaseelan, 1997)

Until now, there are many reports on anaerobic digestion of fruits waste consist of apple, orange, pineapple, sapota, grape, mango and banana (Banu et al., 2007), waste from pea shells (Kali and Joshi, 1995), pineapple wastes and banana peel (Bardiya et al., 1996), spoiled mango puree (Kirtane et al., 2009), combination of fruits peel waste (Srilatha et al.,1995) and banana waste (Zainol, Salihon and Abdul-Rahman, 2008). Therefore, fruits wastes have become one of the selected types of biogas yielding biomass. However, there are no present reports on anaerobic digestion and biogas production from *Benincasa hispida* wastes or also known as Kundur and the potential of the fruit have not yet been discovered.

## 1.2 Problem Statement

The common practice of solid waste management such as fruit and vegetable wastes from agricultural industries are mainly by dumping to the ground and also landfill. Although this kind of excesses are biodegradable and can decompose to the ground in some amount of time, however they generate unpleasant odor to the surrounding, attracting pest such as flies and contribute to an uneconomically way of living. Instead of throwing them as wastes, therefore this research is aimed at the utilization of another type of fruit wastes which is Kundur waste by anaerobic digestion for biogas generation.

## 1.3 Objective

There are two objectives to be achieved in this research. The objectives are:

i) To characterize the composition from Kundur waste.

ii) To identify the percentage sample compositions to produce highest volume of biogas.

## 1.4 Research Scope

In order to achieve the objectives, the scopes involve are:

i) Analysis of the Total Solid (TS), Total Volatile Solid (TVS), Chemical Oxygen Demand (COD), Ammonia-Nitrate, and pH using the standard method.

ii) The sample composition for sample A,B,C,D,and E are 100 wt % ,80 wt %, 60 wt %, 50wt% and 40 wt % of Kundur waste respectively with remaining wt % are cow dung as inoculum.

## 1.5 Significant of Study

The usage of Kundur waste as substrate for biogas production could lead to a new degree of information that wastes from this fruit also suitable as a biomass for yielding biogas. Thus, economical use is developed from another type of wastes present nowadays which is biogas that can be used for energy and also electricity. Furthermore, the residues from the anaerobic digestion of this fruit are likely to have a stabilized state and become a good biodegradable fertilizer in land that can reduce the environmental problem and nuisance.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Definition of Biogas

Biogas is the gases that produce as a result of the action of bacteria and organic waste matter. It is a clean and renewable form of energy that could very well be a substitute for today's conventional sources of energy such as fossil fuel and oil which are not only causing ecological and environmental problems but also some additional effects to human being. Apart from that, at the same time the sources depleting at a faster rate as they are kept on consumed for energy (Santosh et al., 2004). Biogas main component are methane ($CH_4$) and carbon dioxide ($CO_2$). The biogas itself generally comprises of methane, carbon dioxide, nitrogen ($N_2$), hydrogen sulphide ($H_2S$), hydrogen ($H_2$), oxygen ($O_2$) and also ammonia ($NH_3$). The typical percentage composition of biogas is tabulated in Table 2.1.

**Table 2.1** Typical composition of biogas.

| Component | Typical analysis (% by volume) |
|---|---|
| Methane | 55-56 |
| Carbon dioxide | 35-45 |
| Nitrogen | 0-3 |
| Hydrogen suphide | 0-1 |
| Hydrogen | 0-1 |
| Oxygen | 0-2 |
| Ammonia | 0-1 |

(Source: Balat and Balat, 2009)

## 2.2 Availability of Biogas Plant Worldwide

Biogas plant started from ages ago, well-known and can be found almost in every country worldwide. As in Asian country, China own millions of biogas plant but there is some doubt whether all of the biogas plant still in operation (Fischer and Krieg, 2011). This scenario is similar in India which there is millions of biogas plant in the country. These two countries are popular in most of the reported papers about biogas. However, other Asian country such as Vietnam and Thailand also own several biogas plants in their countries. Usually, the designs of the biogas plant are simple, cheap, effective and suitable for household usage. The main components to be feed into the biogas plant are mainly easy to get waste which is from the house itself and also animal dung. Apart from that, many higher institutions there occupy themselves to make research on the optimization of the efficiency for production of biogas.

As in South America, information on the anaerobic solid waste digestion is hardly to find than the anaerobic waste water treatment. Here, there are quite several efforts that had been employing in order to build and implement biogas plant but another factor that prevents them  to do that is not enough of money (Fischer and Krieg, 2011). On the other hand in North America, there is strong effort on the road to the implementation of green energy although North America did not sign the Kyoto Protocol treaty which say, industrialized country will reduce their collective emissions of greenhouse gases by 5.2% compared to the year 1990 where the goal is to minimize the overall emission of the greenhouse gases (United Nations, 1998). Today, the development of the biogas plants there are still in planning and joint venture to more experienced company had been made.

Other than that, countries in Europe such as Denmark and East Germany had taken the step to build a centralized biogas plant while the West Germany is more interested in small farm scale biogas plant.  The biogas plant here is highly developed as compared with other countries and there are many varieties of sizes of biogas plant operated. The growth of biogas in Europe increase 20% from the year 2006 to 2007 with Germany and United Kingdom as the biggest contributor (Rechberger, 2009). The scenario for manure, biogas crops and total biogas potential for selected countries in Europe are as in Table 2.2.

**Table 2.2** Total biogas potential from crops and manure for several countries in Europe.

| Country | Biogas potential from crops (Mt) | Biogas potential from manure (Mt) | Total biogas potential (Mt) |
|---|---|---|---|
| Germany | 2.56 | 0.88 | 3.43 |
| United Kingdom | 1.31 | 0.58 | 1.89 |
| Ireland | 0.23 | 0.88 | 3.43 |
| Italy | 1.55 | 0.40 | 1.94 |

(Source: Rechberger, 2009).

### 2.2.1 Biogas Plant Demand in Malaysia

Malaysia is one of the countries that rich in petroleum resources mainly important in generating electricity. The energy generation in Malaysia is estimated to rise at the annual growth rate of 4.7 percent each year as illustrated in Figure 2.1.

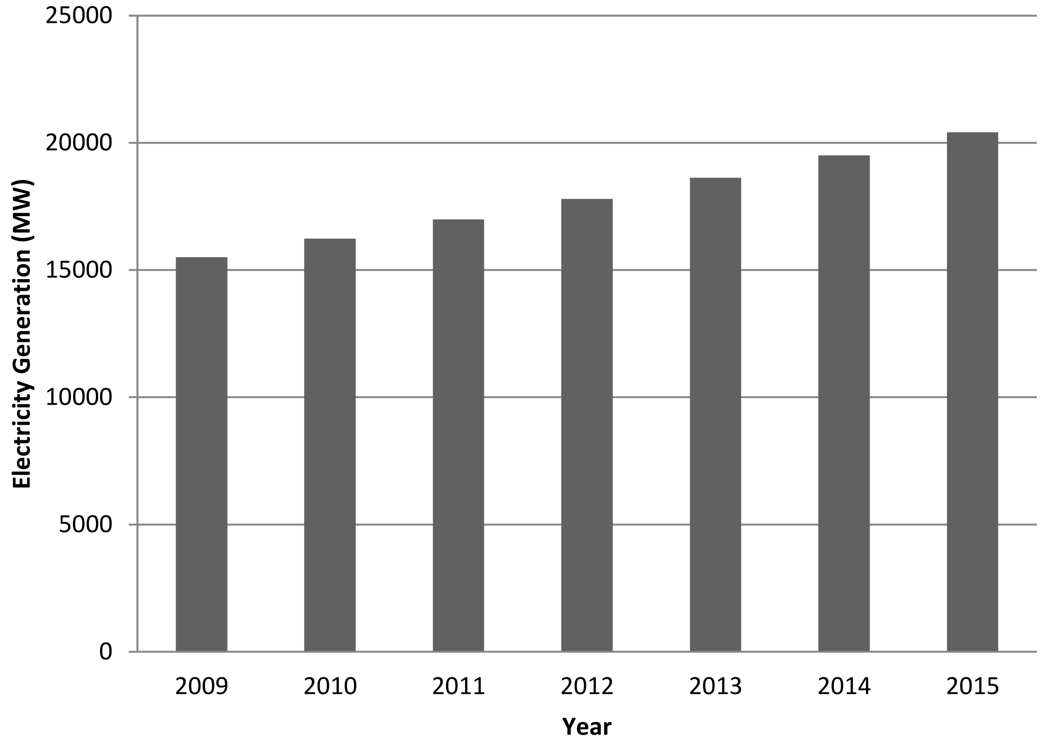


**Figure 2.1** Projection of electricity generation in Malaysia based on average annual growth rate.

In the early year from 2000 to 2009, there is increase about 20% of electricity generation from 13000 MW to 15500 MW respectively (Zafar, 2011). Apart from that, the government of Malaysia had changed the Four-Fuel-Policy to the Five-Fuel-Policy in addition of the potential of renewable energy as listed in Table 2.3 to the original fuel, oil, gas, coal and hydropower under the 8$^{th}$ Malaysia Plan.

**Table 2.3** Renewable energy sources potential in Malaysia.

| Sources | Amount (MW) |
|---|---|
| Biomass | 2400 |
| Biogas | 410 |
| Solar | 6500 |
| Municipal Waste | 400 |
| Mini-hydro | 500 |
| Total | 10210 |

(Source: Zafar, 2011).

## 2.3 Waste Generation in Asia

Waste can be divided into several categories that are residential, commercial, gardens, industrial, agricultural and rural, demolition and construction, transportation, water and waste water treatment plant, beaches and recreation areas, slum, fruit and vegetables market and also slaughter house. As according to the estimation and projection by the World Bank in year 1999, the municipal solid waste (MSW) in rural areas of Asian countries is increasing tremendously from year 1999 to 2025 from around 760000 ton per day to 1.8 million ton per day. The waste quantity for Asian countries up to year 2007 is tabulated in Table 2.4. Here, the MSW include the wastes generated from the domestic, industrial, commercial, institutional, demolition and construction and also municipal services (Chandrappa and Das, 2012).

**Table 2.4** Waste quantity in Asian countries.

| Country | MSW (kg/capita/day) |
|---|---|
| India | 0.46 |
| Bangladesh | 0.49 |
| Nepal | 0.50 |
| Philippines | 0.52 |
| Mongolia | 0.60 |
| Lao PDR | 0.69 |
| Indonesia | 0.76 |
| China | 0.79 |
| Malaysia | 0.81 |
| Sri Lanka | 0.89 |
| Thailand | 1.10 |
| Singapore | 1.10 |
| Japan | 1.47 |

(Source: World Bank, 1999; UNDP, 2007).

In Malaysia for the year 2012, it is estimated that Peninsular alone generated around 25,000 MT of municipal solid waste daily. The percentage of the bulk is food for 48%, paper for 15%, plastic for 14% while remaining for other wastes (Waste Management Conference and Exhibition, 2012). The projection for MSW generation in Peninsular Malaysia based on average increase rate of 2.14% is shown in Table 2.5.

**Table 2.5** MSW generation in Peninsular Malaysia.

| State | 1998 | 1999 | 2000 | 2010 | 2015 | 2020 |
|---|---|---|---|---|---|---|
| Kuala Lumpur | 1058 | 1070 | 1082 | 1202 | 1262 | 1322 |
| Selangor | 1169 | 1204 | 1240 | 1595 | 1772 | 1950 |
| Pahang | 202 | 206 | 210 | 250 | 270 | 290 |
| Kelantan | 123 | 126 | 120 | 87 | 72 | 42 |
| Terengganu | 119 | 122 | 125 | 155 | 170 | 185 |
| N.Sembilan | 267 | 278 | 291 | 411 | 471 | 531 |
| Melaka | 208 | 216 | 225 | 310 | 352.5 | 395 |
| Johor | 927 | 956 | 1005 | 1395 | 1590 | 1785 |
| Perlis | 28 | 28 | 29 | 34 | 36 | 39 |
| Kedah | 569 | 569 | 631 | 941 | 1096 | 1251 |
| Penang | 611 | 611 | 648 | 833 | 925 | 1018 |
| Perak | 719 | 719 | 763 | 983 | 1093 | 1012 |
| Total | 6000 | 6105 | 6369 | 8196 | 9111 | 9820 |

(Source: Tarmudi et al., 2009)

### 2.3.1 Agro-waste Generation in Malaysia.

Agro-waste consists of four main divisions that are animal waste, food processing waste, crop waste and hazardous toxic waste. Animal wastes as for example are manure, animal carcasses, pesticides, insecticides and also herbicides. Crop wastes include cornstalks, sugarcane bagasse, drops and culls from fruit and vegetables. On the other hand, fruit processing waste are the waste resulted from the production of processed food such as canned food, juices and beverages while the hazardous and toxic waste are the pesticides, insecticides and herbicide used in maintaining the crops in agricultural industry. Up till year 2009, 998 million ton of agricultural wastes are produce in a year worldwide while Malaysia constitute 0.12% from the total waste and disposed to landfills (Agamuthu, 2009). The total agricultural waste and projected waste generated in year 2025 base on Asian countries are listed in Table 2.6.

**Table 2.6** Agro-waste generation in Asian country.

| Country | Agricultural Waste Generation (kg/cap/day) | Projected Agricultural Waste Generation in 2025 (kg/cap/day) |
|---|---|---|
| Brunei | 0.099 | 0.143 |
| Cambodia | 0.078 | 0.165 |
| Indonesia | 0.114 | 0.150 |
| Laos | 0.083 | 0.135 |
| Malaysia | 0.122 | 0.210 |
| Myanmar | 0.06 | 0.128 |
| Philippines | 0.078 | 0.120 |
| Singapore | 0.165 | 0.165 |
| Thailand | 0.096 | 0.225 |
| Vietnam | 0.092 | 0.150 |

(Source: Agamuthu, 2009)

Based on the Table 2.6, it can be seen that the agricultural waste generation will definitely rising for year to year as shown from the projected waste generation value based on the country, Due to that, this requires more efficient way needed to be implemented in treating the waste.

## 2.4 Conventional Way for Agricultural Waste Treatment

Agricultural industries in Malaysia and other countries produce huge amount of agro-waste and proper treatment need to be done. Without correct treatment , problems to human health , unpleasant odor and causing nuisance may occur. Treatment can help improve the physical properties of waste and reduce its toxicity while generating a better residue with some beneficial aspect (Sudrajat, 1990; Marchaim et al.,1991; Vermeulen et al., 1992). The conventional method that mostly use in treating agricultural waste involved open burning and also incineration.

### 2.4.1 Open Burning

Open burning is the combustion of waste that occurs in open area without having a smoke stack or any proper smoke management tools as for example is the burning of waste on the ground or could be in barrels. One of the effect of open burning is mainly the emissions of pollutant including soot, particulate matter, carbon monoxide, volatile organic carbon and semi-volatile organic carbon (Lemieux et al.,2004). Although open burning might cost very little amount of money, however this practice provide no benefits but harm to environment.

### 2.4.2 Incineration

Incineration is the process of setting fire or thermal level to destroy the waste. Waste incineration is the worst category of biomass. Providing increased waste disposal capacity worsens the waste problem by lowering the costs associated with waste generation. It also destroys resources some of which are best recycled or composted and turns them into toxic ash and toxic air emissions. Wastes that cannot be reused, recycled or composted cleanly sometime ought to be stabilized through digestion, then landfilled rather than incinerated. Incinerators also emit indirect greenhouse gases such as carbon monoxide (CO), nitrogen oxide (NOx), non-methane volatile organic compounds (NMVOCs), and sulfur dioxide (SO2) (Hogg, 2006; Rabl et al.,2007). As according to U.S. Environmental Protection Agency (EPA), U.S incinerators are among the top 15 major sources of direct greenhouse gases to the atmosphere that are listed in the US EPA's most recent inventory of US greenhouse gas emissions. This proved that although incineration process might be one of the good method for destroying potentially infectious agents however, its usage still provide bad effect to human and surrounding.

## 2.5 Anaerobic Digestion.

Anaerobic digestion is a crucial biological conversion process to treat the biodegradable portion of waste that arrived from agricultural industry, forestry, food processing, municipal solid waste, aquatic biomass and others.

### 2.5.1 Anaerobic Digestion History

The history of anaerobic digestion indicates that biogas firstly was used for heating bath water in Assyria during the l0$^{th}$ century BC and in Persia during the 16$^{th}$ century. Jan Baptita Van Helmont is the first person that determined the flammable gases could evolve from decaying organic matter. Count Alessandro Volta concluded in 1776 that there was a direct correlation between the amount of decaying organic matter and the amount of flammable gas produced. In 1808, Sir Humphry Davy determined that methane was present in the gases produced during the AD of cattle manure (Tietjen, 1975). As according to Meynel, (1976), the first digestion plant was built at a leper colony in Bombay, India in 1859. The development of microbiology as a science led to research by Buswell (1936) and others in the 1930s to identify anaerobic bacteria and the conditions that promote methane production.

### 2.5.2 Anaerobic Digestion Process

Within this process, biomass are converted to methane and hydrogen which very economically beneficial in the absence of oxygen and leaves a stabilized residue (Mallick et al., 2009). The overall process can be shown as follow.

Organic matter + seed $\longrightarrow$ $CH_4$ + $CO_2$ + $H_2S$ + $NH_3$ + other end product +energy

(Evans,2001)

There are three important stages in biogas generation which are hydrolysis, acidogenesis and also methanogenesis. Each stages convert different chemicals with different products. Simplified diagram for the anaerobic digestion process of fruit and vegetable waste is shown in Figure 2.2.

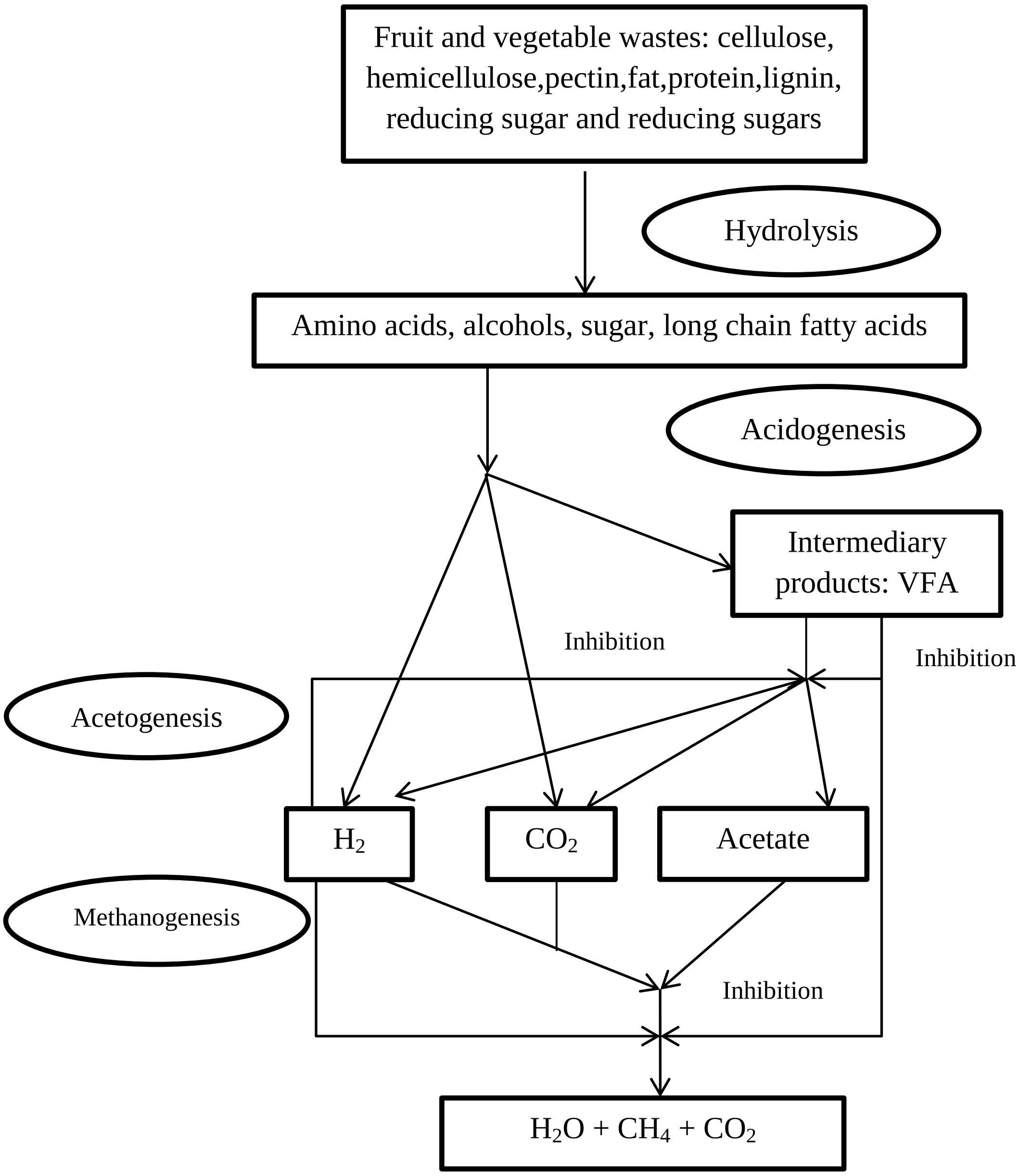


**Figure 2.2** Reactions scheme for anaerobic digestion of particulate organic material of Fruit and Vegetable Waste (Source: Bouallagui et al., 2005).

#### 2.5.2.1 Hydrolysis

The first step in the anaerobic biodegradation process is hydrolysis. It involves the conversion of the insoluble organics into soluble products by the action of the hydrolytic bacteria or known as hydrogen producers (Kalia and Joshi,1995). Proteins present in the waste are converted into amino acids, fats into long chain fatty acids and carbohydrates into simple sugars. This product ready to be used by acidogens in next stage.

#### 2.5.2.2 Acidogenesis

Also known as acid formation step. The simple sugars and amino acids released in earlier stage are degraded by the acidogens to produce an intermediary products known as volatile fatty acids (VFA),acetate, hydrogen ($H_2$) carbon dioxide ($CO_2$). The hydrogen-producing acetogenic bacteria or acetogenesis helps convert long chain fatty acids and higher volatile fatty acids to acetate, hydrogen ($H_2$) carbon dioxide ($CO_2$) (Zaman,2010).

#### 2.5.2.3 Methanogenesis

The third stage involves methanogens that convert product from previous stage which are acetate, $H_2$ and $CO_2$ into $CH_4$ and $CO_2$.

## 2.6 Biogas from Fruit Waste.

Much of the literatures in recent years had reports on biomethanation of various fruit waste. In research by Banu et al.,(2007), the solid state biomethanation of fruit wastes comprising of apple, orange, pineapple, sapota, grape, mango and banana show that methane generation increased from $0.006m^3/day/m^3$ to $0.35m^3$ with increasing in total solid. According to Kirtane et al.,(2009) biomethanation of mango puree produce biogas containing 65% methane and increase to 78% methane upon stabilization. This indicate that fruit waste possess a strong substrate for anaerobic digestion. Moreover, reports on biogas production from banana peel and pineapple waste show that a maximum rate of methane production of 0.93 vol/vol/day with 58% utilization (Bardiya et al.,1996). While Bouallagui et al.,(2005) also support that fruits waste in anaerobic digestion could produce 0.16 to 0.47litre/gVS of methane yield depending on the process and type of reactor, however there is a major limitation of anaerobic digestion of fruit waste which is rapid acidification and larger fatty acid production that can inhibit the methanogens. One the other hand, much of those literatures support that biogas generation from fruit wastes can generate methane gas and this strengthen the potentiality of Kundur wastes in biogas production as there is no references have been done by using this fruit yet.

## 2.7 *Benincasa hispida* in Anaerobic Digestion.

One of the type of fruit waste that can be investigated its potential is *Benincasa hispida.* There are many literatures on the utilization of fruit wastes such as pineapple, papaya, orange, pea, apple and others however none had using this fruit as substrate yet.

### 2.7.1 Background of *Benincasa hispida.*

*Cucurbitaceae* (Cucurbit) is an important family comprising one of the most genetically diverse groups of food plants. Some important Cucurbit family members include; gourd, melon, cucumber, squash and pumpkin. *Benincasa hispida* (Thunb.) Cogn. (synonym; *Benincasa cerifera*) is one of the most valuable plants in Cucurbit family. It is also known as Kundur (Malay), ash gourd or winter melon (English), Bhuru Kolu or Safed Kolu (Gujarati), Petha (Hindi), Kushmanda (Sanskrit), Donggua (Chinese) and Beligo (Indonesian). This fruit also sometimes called fuzzy melon, wax guard, winter guard, ash gourd. Its peel contains high edible waxy materials. The composition of Kundur is stated as in Table 2.7.

**Table 2.7** Typical composition of Kundur

| Composition | Measurement |
|---|---|
| Moisture (%) | 96.50 |
| Fibres (%) | 0.80 |
| Carbohydrates (%) | 1.90 |
| Protein (gm/100gm) | 0.40 |
| Mineral Matter (%) | 0.30 |
| Fats (gm/100gm) | 0.10 |
| Calcium (U.l/mg) | 30.00 |
| Phosphorus (U/l/mg) | 20.00 |
| Vitamin C (U.l/mg) | 1.00 |
| Iron (U.l/mg) | 0.80 |
| Copper (U.l/mg) | 0.07 |
| Iodine (U.l/mg) | 0.04 |

Kundur often used to produce beverages, jams, cordial and thickening. The *Cucurbitaceae* family is mostly distributed around the tropical regions and the winter melon, which has been cultivated for at least 2,000 years, originated from south-east Asia (Mohd Zaini,et al.,2011). As shown in Figure 2.3, this fruit is large and seedy with white colored spongy flesh and also waxy skin which prevents microorganisms from attacking it and preserves it. Depending on the shape, type and maturity of the fruit, the seeds, which are smooth and white to yellowish-colored, fill the centre of the fruit (Raveendra and Martin, 2006). Data from the Index of Nutritional Quality (INQ) shows that Kundur is valued as a high quality vegetable and according to Warisan Kundur Resources, one of the Kundur processing industry in Pahang, there are various benefits of Kundur for human health such as medicine for diabetes, fever, scars, swollen and others. Usually, this type of plant is cultivated on a wide area of ground throughout India, South East Asian countries, Japan, China, and also Australia.

**Figure 2.3** *Benincasa hispida*

### 2.7.2 Type of Kundur Waste.

Wastes from Kundur mainly consist of its peel because most Kundur processing industry uses the Kundur's edible portion as raw material. According to Jain et al. (2010) the thick peel of Kundur is thrown as waste material in the surrounding since its economical used not yet has been developed. The peel gives remarkable shelf life to the fruit inside and 15% of Kundur are mainly disposing as waste which also including its seed and others part of Kundur such as stem and leaves (Sreenivas, Chaudhari and Lele, 2010). This supported by Sew et al. (2010) that the remaining portion of the Cucurbits fruits especially the seed often discarded as agro waste but it can be used for other applications such as oil extraction and preservative with other specific processes.

In addition, Anwar et al. (2011) also stated that winter melon fruits or Kundur produce huge amount of seeds and usually been thrown away and cause environmental problem. This is also supported by Kumar et al. (2012), that process of making health products from Kundur such as hair product involve of burning the rind and seeds which then mixed with coconut oil. Thus this explained that Kundur has been a part of human diet for years due to its inexpensive, versatile, healthful and high nutritional values. On the other hand, the consumption of these fruit generates peel wastes that could bring about environmental pollution if not properly handled. The common usage of Kundur fruit of fresh weight is shown as in Figure 2.4.

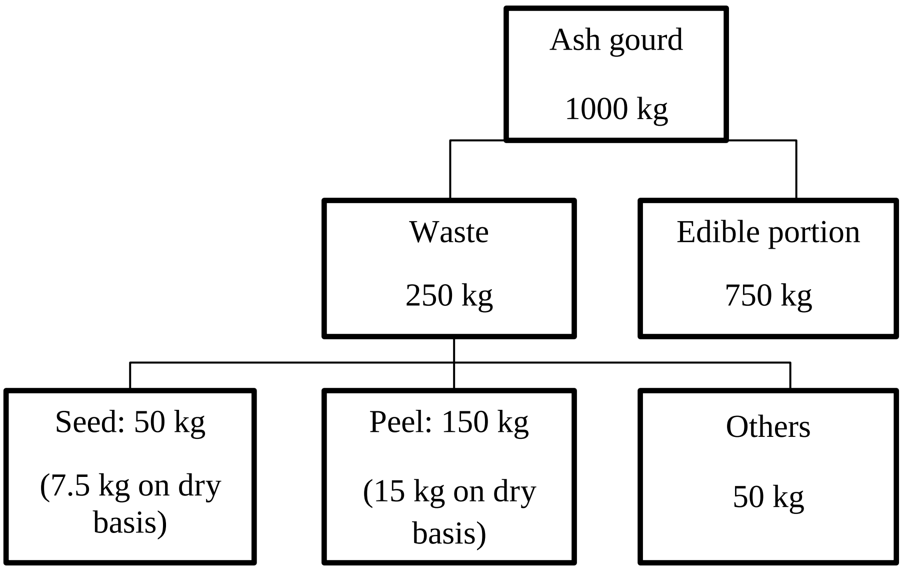


**Figure 2.4** Flowchart showing common material balance of Kundur for industrial purposes. (Source: Sreenivas, Chaudhari and Lele, 2010).

## 2.8 Parameters in Anaerobic Digestion

There are many factors that affect anaerobic digestion process. This is because the microorganisms may vary according to the steps involved. The main parameters are temperature, retention time, pH level, total solid, and inoculum.

### 2.8.1 Temperature

There is wide range of temperature that can be used because it depends on microorganisms used in research. Many research had been perform under temperature conditions, of psychrophilic (15-25$^{o}$C), mesophilic (30-37$^{o}$C), or thermophilic (55-65$^{o}$C) temperature conditions (Chynoweth and Isaacson, 1987). However, a study by De Baere (2000) found that most anaerobic treatment plants in Europe operated at mesophilic conditions, because at mesophilic temperature, it could be more suitable as a matter of operation to ease, less heating requirements and can enhanced process stability. Khalid, Arshad, Anjum, Mahmood, and Dawson (2011) stated that lower temperature during the process is known to decrease the microbial growth, substrate utilization rates and biogas production. In contrast, Khalid et al. (2011) also mentioned that highest temperatures yields lower biogas due to production of volatile gases such ammonia which suppress methanogenic activities. Hence, anaerobic digestion is carried out at mesophilic temperature. This is due to the operation in mesophilic seemed to be more stable and requires a smaller energy expense. Mesophilic bacteria are supposed to be more robust and can tolerate greater changes in the environmental parameters including temperature (Nayono et al., 2009). The overall influences of temperature are shown in Figure 2.5. Therefore, within this research, a mesophilic temperature will be used as the incubation temperature to provide a suitable surrounding to the process.

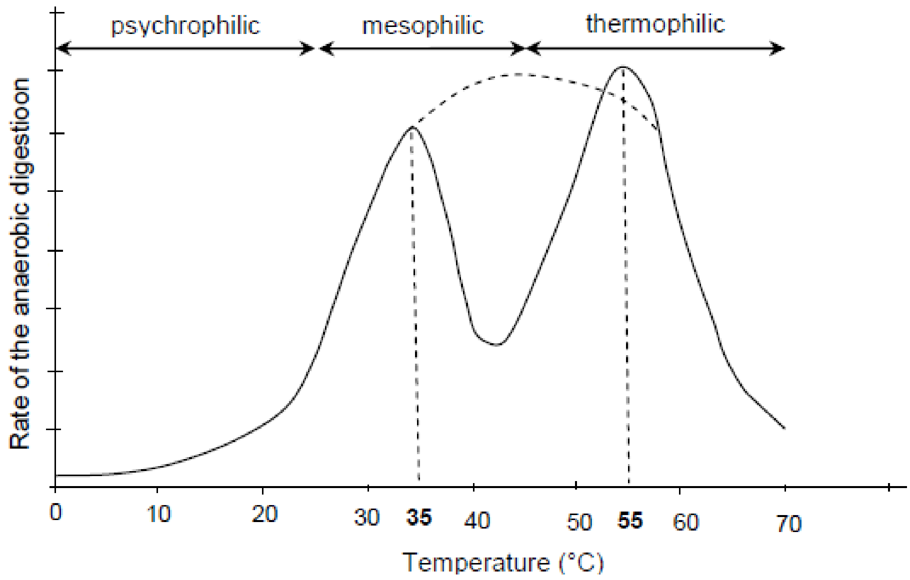


**Figure 2.5** Influence of temperature on the rate of anaerobic digestion process (Source:Mata-Alvarez, 2002).

### 2.8.2 Hydraulic Retention Time

Hydraulic retention time (HRT) can be defined as a measure for the average time for substrates be present in the anaerobic digester. In order to achieve a fully 100% methane generation form waste, it could take until infinite amount of time (Zaman, 2010). An incubation period of 60 days is recommended by ISO 11734 (1995) and Shelton and Tiedje (1984). However, any plateau or constant in methane generation before the recommended time is possible since methane generation does not have the same fixed time to stop produce or vice versa and early stop of digestion is applicable if the desired HRT is obtained. On the other hand, other researchers take the period between 10 to 14 days to achieve the benchmark which is 95% of subsrate degradation. (Nopharatana et al.,2007). Shortening the HRT will reduces the size of digester and eventually lowering the capital cost. Shorter HRT also been reported to yields higher biogas production rate (Nayono, 2009). On the other hand, Hartman and Ahring (2006) reviewed that from others researchers, the HRT is dependent on the type of waste, operational temperature, process stage and configuration of digester.

### 2.8.3 pH Value

The optimum pH for anaerobic digestion is normally in the range of 7 to 8, pH levels that out from this range can indicate potential toxicity, digester sour, and failure. Chua et al. (2008) mentioned that methane producing bacteria require a neutral to slightly alkaline environment (pH 6.8 to 8.5) in order to produce methane. Low pH levels, for example, can be a symptom of digester imbalance. As volatile acids concentrations increase, the pH in the digester decreases. As pH levels fall below 6.0 to 6.5, the acidic conditions produced become increasingly toxic to methane bacteria. In order to control pH in laboratory-scale digesters, sodium bicarbonate (Na2CO3) is frequently added either in place of or in addition to sodium hydroxide (NaOH)(Zaman,2010). Biey et al. (2003) found that if the pH is corrected from the beginning, the biogas production from vegetable fruit garden waste can be shortened to less than 2 months. When buffer was added to the reactors at the beginning, the pH of the digester was maintained above 7.0 and within the optimal range for methanogens activity (Raposo et al., 2006).

### 2.8.4 Total Solid

Total solid concentration is the amount of solid placed inside the anaerobic digester and diluted with water until a marked up volume desired. In study by Budiyono et al.,(2010), the result of biogas yield from cattle manure using rumen fluid as inoculum show that the best performance of the digester with 7.4 and 9.2% total solid gave biogas yield 184.09 and 186.28 ml $gVS^{-1}$ respectively. The lesser total solid gave a less biogas yield and thus too low total solid are not suitable for biogas production. Moreover, if a process inside the anaerobic digester operate with high solid content, this will decrease the digester volume as the volume of the water is also decreased. This supported by Muryanto et al.,(2006) and Balsam (2002) that the optimum solid content for biogas production is around 7 to 9% total solid. Higher total solid will decrease the cumulative biogas produced (Sadaka and Engler, 2003). Apart from that, a study by Igoni et al.,(2008) showed that increasing the total solid from 4 to 10% resulting in increased of volume of biogas from $66.98m^3$ to $200.22m^3$. This mean that 10% total solid is quite reliable as optimum total solid to be implement into this research. On the other hand, the solid content of 12 to 14% total solid of swine manure, it produced more biogas than the higher initial solid contents. The biogas yield for the low total solid is $0.5m^3$/kg VS while higher total solid only yield $0.2m^3$/kg VS (Sadaka et al., 2003). Moreover, Hill (1983), Jewell and Loehr (1977) and Morris et al.,(1975) reported that using a high total solid of 20-25% in poultry manure , a reduction of process performance is observe. This mean that high total solid content is not a good approach and 9 to 10% is the best total solid concentration.

### 2.8.5 Inoculum

Inoculum for anaerobic digester can be collected from various source depending on the substrate used such as from the environments in which the anaerobic methanogenic decomposition of organic compounds occurs naturally, for example, anaerobic sewage digesters, anaerobic lake sediments or from animal manure. In research by Neo et al., (2012), the inoculums used are activated sludge and also cattle manure. Result showed that the biogas production from wheat straw inoculated with activated sludge and cattle manure are 47% and 59% respectively. The cow manure concludes that it can be used for anaerobic fermentation of agricultural waste for biogas production. Furthermore, the effectiveness of cow dung for biogas production also proved when Abubakar and Ismail (2012), reported that cow dung digestion approximately achieves 47% Volatile Solid reduction and approximately 48.5% COD reduction with yielded biogas of 0.15 L/biogas/kg $VS_{added}$ and this resulted that cow dung is suitable feedstock for biogas production.

## 2.9 Co-digestion of Substrate

Co-digestion in anaerobic digestion is the process where two or more inputs are added for a simultaneous digestion. Co-digestion had been an interesting approach to improve the efficiency of biogas production (Nayono,2009). According to Mata-Alvarez et al.,(2003), one of the main thing that need to be considered for co-digestion of substrate is the additional pre-treatment process and the homogenization in the digestor. However, co-digestion is attracted in a way that the micro and macro of nutrient from both substrates can be achieved. In a report by Iyagba et al.,(2009), the study of cow dung as co-substrate with rice husk in biogas production showed that the highest yield for biogas is for the sample proportion of cow dung: rice husk (50:50) by weight percent basis which is 161.5ml. The sample proportion for 100% of rice husk revealed none production of biogas. This clearly indicates that co-digestion really improve the yield of biogas. In another study of biogas production from the mixed fruit waste with cow dung, the sample of fruit waste co-substrate with cow dung show a steep increase in biogas volume with almost three fold as compared to the sample containing digested fruit waste alone ( Narayani and Priya, 2012). The usage of animal manure for co-digestion had been used almost 2000 years ago. There are a lot of advantages in using animal manure as its availability is abundant, high buffer potential due to tis ammonia content and higher biogas production .

## 2.10 Advantages of Anaerobic Digestion

Biogas generation is one of the beneficial methods today. Human especially can gain the benefits of biogas production such as odor control, renewable energy production, electricity generation, fertilizer production and pathogen reduction.

### 2.10.1 Odor Control

Regardless of many benefits linked with anaerobic digestion, one of the major reasons anaerobic digestion widely applied is due to the ability of odor control. This action lead to reduction of odor up to 80% as it reduces the soil and water contamination by decreasing the disposal of untreated waste and animal manure or slurries. (Monnet, 2003). Worldwide usage of anaerobic digestion is prominent among the farmers, rural areas citizens, wastewater industry and other industries which releases high odor to the environment. Odor free process is the natural result from the anaerobic digestion. Susan (2011) stated in her Minnesota Project that anaerobic digestion functions to reduce the odor from the wastes by stabilizing the organic material in the waste that are responsible for undesirable odor. This can be done by the process to break down the highly odor organic waste with the aid of bacteria. Fly propagation also will be controlled compared to fresh manure and digested manure (Nelson et al., 2002).

### 2.10.2 Renewable Energy Production

Anaerobic digestion system will also permit for the production of renewable energy. Some of the other methods are suitable to transform the waste into odor free waste however not suitable for producing energy. This is different from anaerobic digestion. According to Nelson et al. (2002) using the gas to generate energy may compromise a significant economic payback depending on farm scale. Most usually the gas is burned in an engine-generator to generate electricity, and the waste heat can also be utilized to be used in creating hot water for heating the digester.

### 2.10.3 Electricity Generation

From a statistics by Susan Reed (2011), the majority of 85 % anaerobic digester projects in the United States utilize biogas produced by the anaerobic digester to generate electricity. From those projects, anaerobic digesters generate around 331 million kW of electricity annually. The generated electricity can be applied for electricity utility, including voltage support and power loss reduction through transmission.

### 2.10.4 Production of Fertilizer

The amount of fertilizers can be commercially produced by using anaerobic digestion. Turning waste into fertilizers is a vast gain to the industry as the cost for producing synthetic fertilizers can be reduced. Erickson et al. (2004) said that the digestion process converts organic nitrogen into a mineralized form (ammonia or nitrate nitrogen) that can be taken up more quickly by plants than organic nitrogen. It is also believed that the fertilizers produced have better efficiency and nutrients for the plant to absorb and grow. In a report by Manikam,(2012), the plant growth where it had been supply with the residue from the anaerobic digestion showed higher growth rate than the one without the supplementation of residue.

# CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 Kundur Waste Preparation.

Wastes consist mainly of Kundur's peel as in Figure A.1 in appendix were collected from Warisan Kundur processing industry located in Pekan, Pahang. Kundur waste were collected and were kept inside a sealed polyethylene bag and store at $4^{o}C$ until further used. The waste were shredded to small particles and homogenized to facilitates digestion (Bouallagi et al., 2005), and mincing since it helps degradation easily (Mallick et al.,2009).

## 3.2 Cow Dung Preparation

The cow dung as in Figure A.2 in appendix is collected from a private farm in Felda Lepar Hilir, Gambang. The cow dung are stored in polystyrene box and kept in the raw material area in the laboratory for further used. The cow dung is crushed manually with pestle and mortar to ensure homogeneity (Iyagba et al., 2009).

## 3.3 Parameters of Biogas Production and Selected Operating Conditions

The research was carried out under room temperature which around 30$^{o}$C to 37$^{o}$C that represents the mesophilic and the best temperature for biogas production (Nayono et al., 2009). Initial pH values for samples A,B,C,D and E are 7.02, 7.18, 7.23, 7.35, and 7.47 which all fall within the pH range for biogas production. In order to adjust the desired initial pH, different amounts of hydrochloric acid (0.1N $HCl$) and sodium hydroxide (0.1N $NaOH$) were used (Cubilos et al,2010).

## 3.4 Water Content

The water content for each sample was determined using the recommendation for better biogas production as reported by Igoni et al.,(2008) and Sadaka et al., (2003) that is a total solid of 10% in the fermentation slurry. This was the basis for the determination of the amount of water to be added for any given mass of total solid. Hence, there would be the equal proportion solid to water to all the samples.

## 3.5 Sample Proportion

For the purpose of this research, there were six x:y proportions aimed at investigating the efficiency of Kundur waste in biogas production. The six proportions were as follow: A; 100:0, B; 80:20, C; 60:40, D; 50:50 and E; 40:60 for Kundur waste: cow dung on weight percent basis as in Table 3.1.

**Table 3.1** Proportion substrate in each sample.

| Samples (Proportion) | % of x | % of y |
|---|---|---|
| A | 100 | 0 |
| B | 80 | 20 |
| C | 60 | 40 |
| D | 50 | 50 |
| E | 40 | 60 |

x represent Kundur waste; y represent cow dung

## 3.6 Apparatus Setup.

All apparatus were properly washed with soap solution and allowed to dry in oven for glassware drying in the laboratory. 2 Liter conical flask contain the fermentation slurry was connected by two connecting tubes for nitrogen flushing for

15 minutes and another one for collecting gas as illustrated in Figure A.2. The tube for collecting gas was connected to a water displacement apparatus which consist of inverted measuring cylinder in a beaker hold by the retort stand. Biogas produced in the digester passed through the collecting gas tube and pressure build by the biogas caused a displacement of the water inside the measuring cylinder to the beaker. Difference in volume before the water displacement occurs and after displacement has taken place is measured as the volume of biogas produced. The experimental set up is shown in Figure A.3 in appendix.

## 3.7 Analytical Method for Characterization of Kundur Waste and Effluent

Wastes from Kundur and effluent from anaerobic digestion are characterized to determine its Total Solid(TS), Total Volatile Solid (TVS), Chemical Oxygen Demand (COD), Ammonia-Nitrogen, and pH using the standard method.

### 3.7.1 Total Solid (Standard Methods 2540G,1998)

A sample is evaporated in a weighed dish and dried to constant weight in an oven at 103 to 105°C. The increase in weight over that of the empty dish represents the total solids. The total solids in percentage of wet sample are calculated as:

$$\% \, Total\ solids = \frac{A - B\ x\ 100}{C - B}$$

Where, A = weight of dried residue + dish (g)

B = weight of dish (g)

C = weight of wet sample + dish (g)

D = weight of residue + dish after ignition (g)

### 3.7.2 Total Volatile Solid (Standard Methods 2540G,1998)

The residue from the total solids determination is ignited to constant weight at about 550°C. The weight lost on ignition is the volatile solid while the remaining solids represent the suspended solid or fixed solid.. TVS offers a rough approximation of the amount of organic matter present in the solid fraction of wastes. The calculation is as below:

$$\% \, Total \; volatile \; solids = \frac{A-D \; x \; 100}{A-B}$$

Where, D = weight of residue + dish after ignition (g)

### 3.7.3 Chemical Oxygen Demand (COD)

COD was analysed on filtered sample. COD analysis is performed using the Hach Dichromate Reactor Digestion Method test, where small volumes of sample are pipetted into COD reagent vials. The COD values are determined colometrically on a Hach Spectrophotometer using program 435 (high range) where the detectable COD concentration ranges from 0 - 1500 mg/l. The method involves sample digestion for

2 hours at 150°C. Samples are diluted with distilled water if the COD concentration falls over range and the same test procedure is repeated ( Andrew et al.,2005).

### 3.7.4 Ammonia-Nitrate Analysis. (Hach Method 8155, 2004)

Ammonia was determined using HACH Spectrophotometer DR/2400 @ DR/2800, Ammonia Salicylate and Ammonia Cyanurate as the reagents. The method was Method 10031, the Salicylate Method. After a 20 minutes reaction time, sample analyzed using the Hach Spectrophotometer under program 385 N, Ammonia, Salic, the ammonia concentration between 0 – 50 mg/l can be detected .If the ammonia value is over range, samples will be diluted with distilled water and analysis is repeated.

### 3.7.5 Measurement of pH

The pH value is determined using pH meter. Instrument will be calibrated first at the laboratory according to the Instruction Manual if deteriorating quality is detected.

## 3.8 Summary of Process

The summary of whole process from preparation to the measuring of biogas volume is as in Figure 3.1

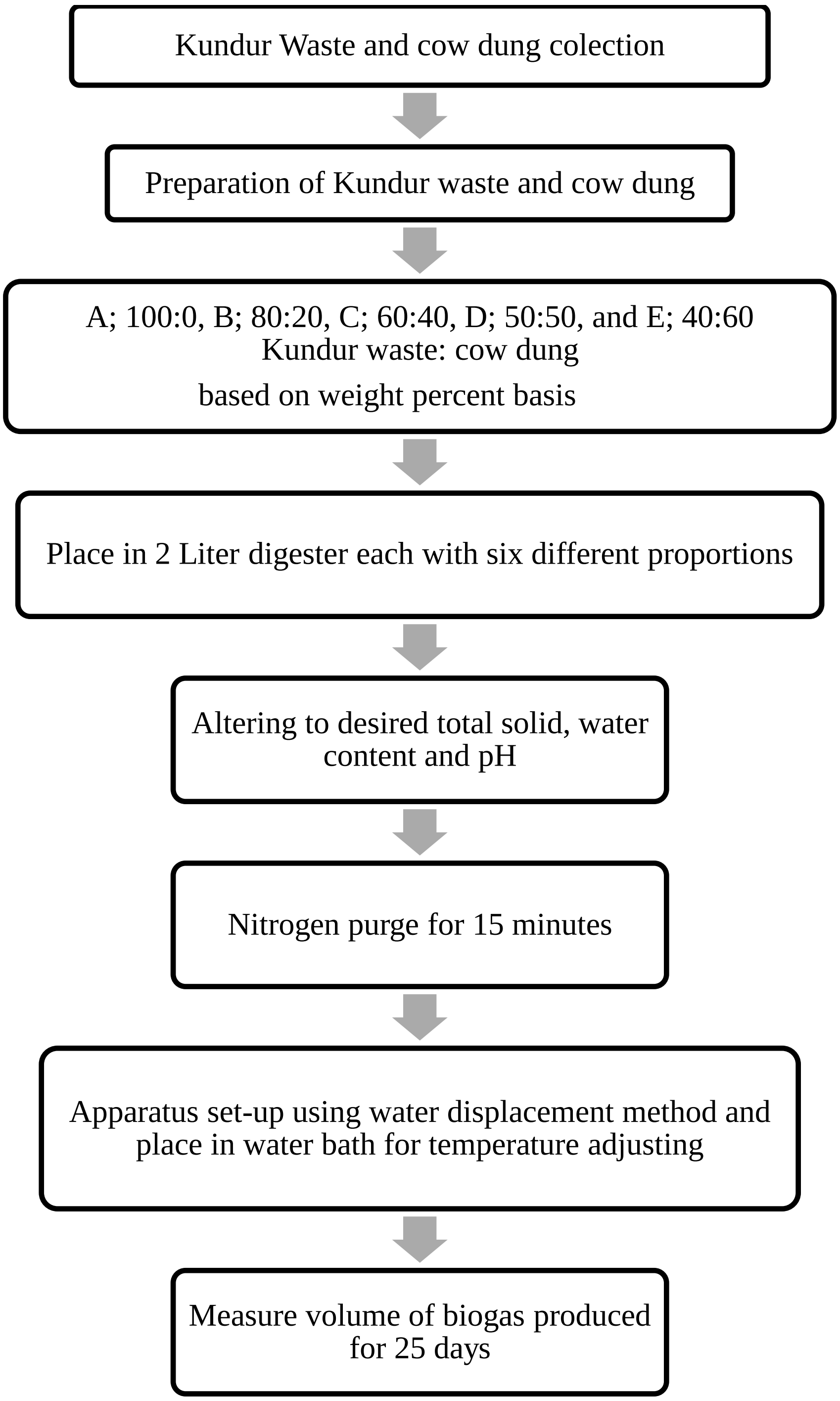


**Figure 3.1** Summary of methodology process.

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.1 Characterization of Kundur Waste

The composition of Kundur waste for characterization is presented in Table 4.1

**Table 4.1** Average composition of Kundur waste used.

| Parameters | Kundur waste |
|---|---|
| TS % | 64.09 |
| VS % | 93.17 |
| COD (mg/l) | 21330 |
| $NH_3$-N (mg/l) | 14.7 |
| pH | 4.34 |

While the average composition of cow dung for characterization is presented in Table 4.2.

**Table 4.2** Average composition of cow dung used.

| Parameters | Cow dung |
|---|---|
| TS % | 68.5 |
| VS % | 79.2 |
| COD (mg/l) | 6900 |
| $NH_3$-N (mg/l) | 680 |
| pH | 7.1 |

As a consequence of different nature of substrates available, Kundur waste specifically defined by different characterization. The waste was characterized by Total Solid (TS), Volatile Solids (VS), Chemical Oxygen Demand (COD) , Ammonia-Nitrate ($NH_3$-N) and pH where measured using the standard method during the experimentation. Total solid indicate the amount of solid remaining after all the volatile matter has been removed from amount of sample at heating value of 105$^{o}$C where volatile solid indicate the portion of total solid that undergo volatilization under heating value 550$^{o}$C. Meanwhile COD is the measure of total quantity of oxygen that required to oxidize the organic material present in the waste.

The value of VS and COD for Kundur waste is quite high. High value of VS and COD are favorable for anaerobic digestion (Tewelde,2012). However, there is no literature found for characterization of Kundur waste to be compared if they are in accordance with information in other reports. The pH for Kundur waste is slightly acidic which is not satisfactory as feed for biogas generation however it is neutralized easily by the addition of cow dung which tend to be more alkaline or by addition of 0.1N NaOH. Manure digesters mainly from cow dung possess a great buffer capacity and high ammonia content than other waste which means it required more acid to reduce the digester's pH, consequently making pH stable around initial value while VFA concentration can be tolerated before pH drop (Pind et al., 2003).

## 4.2 Biogas Production

The biogas production at different time interval are measured for sample A, B, C, D and E. The composition for sample A, B, C , D and E are shown in Table 4.3.

**Table 4.3** Composition of Kundur and cow dung in sample A, B, C, D and E

| Sample | Kundur (wt %) | Cow dung (wt %) |
|---|---|---|
| A | 100 | 0 |
| B | 80 | 20 |
| C | 60 | 40 |
| D | 50 | 50 |
| E | 40 | 60 |

The daily and cumulative production of biogas for all five samples within 25 days of hydraulic retention time are tabulated and shown in Table 4.4. Daily measurement were observed on the volume of water displaced inside the measuring cylinder. Each measuring cylinder was refilled with water if the water level is too low.

**Table 4.4** Biogas production for daily and cumulative for sample A, B and C.

| Day | A (ml) Daily | A (ml) Cumulative | B (ml) Daily | B (ml) Cumulative | C (ml) Daily | C (ml) Cumulative |
|---|---|---|---|---|---|---|
| 1-5 | 0 | - | 0 | - | 0 | - |
| 6 | 0 | - | 5 | 5 | 0 | - |
| 7-9 | 0 | - | 0 | - | 0 | - |
| 10 | 0 | - | 1 | 6 | 5 | 5 |
| 11 | 0 | - | 0 | - | 5 | 10 |
| 12 | 0 | - | 24 | 30 | 24 | 34 |
| 13 | 0 | - | 0 | - | 15 | 49 |
| 14 | 0 | - | 0 | - | 10 | 59 |
| 15 | 0 | - | 0 | - | 12 | 71 |
| 16 | 0 | - | 0 | - | 5 | 76 |
| 17 | 0 | - | 0 | - | 10 | 86 |
| 18 | 0 | - | 0 | - | 15 | 101 |
| 19 | 0 | - | 0 | - | 25 | 126 |
| 20 | 0 | - | 0 | - | 20 | 146 |
| 21-25 | 0 | - | 0 | - | 0 | - |

**Table 4.5** Biogas production for daily and cumulative for sample D and E

| Day | D (ml) Daily | D (ml) Cumulative | E (ml) Daily | E (ml) Cumulative |
|---|---|---|---|---|
| 1-2 | 0 | - | 0 | - |
| 3 | 3 | 3 | 21 | 21 |
| 4 | 2 | 5 | 30 | 51 |
| 5 | 3 | 8 | 5 | 56 |
| 6 | 3 | 11 | 10 | 66 |
| 7 | 40 | 51 | 5 | 71 |
| 8 | 25 | 76 | 0 | - |
| 9 | 30 | 106 | 0 | - |
| 10 | 0 | - | 5 | 76 |
| 11 | 0 | - | 0 | - |
| 12 | 0 | - | 35 | 111 |
| 13 | 40 | 146 | 0 | - |
| 14 | 36 | 182 | 0 | - |
| 15 | 24 | 206 | 0 | - |
| 16 | 20 | 226 | 0 | - |
| 17-18 | 0 | - | 0 | - |
| 19 | 5 | 231 | 0 | - |
| 20 | 0 | - | 0 | - |

**Table 4.5** Continue

| Day | D (ml) Daily | D (ml) Cumulative | E (ml) Daily | E (ml) Cumulative |
|---|---|---|---|---|
| 21 | 0 | - | 5 | 116 |
| 22 | 3 | 234 | 0 | - |
| 23-25 | 0 | - | 0 | - |

The biogas generation for daily and cumulative production for all the digesters involved are also ilustrated in Figure 4.1 and 4.2.

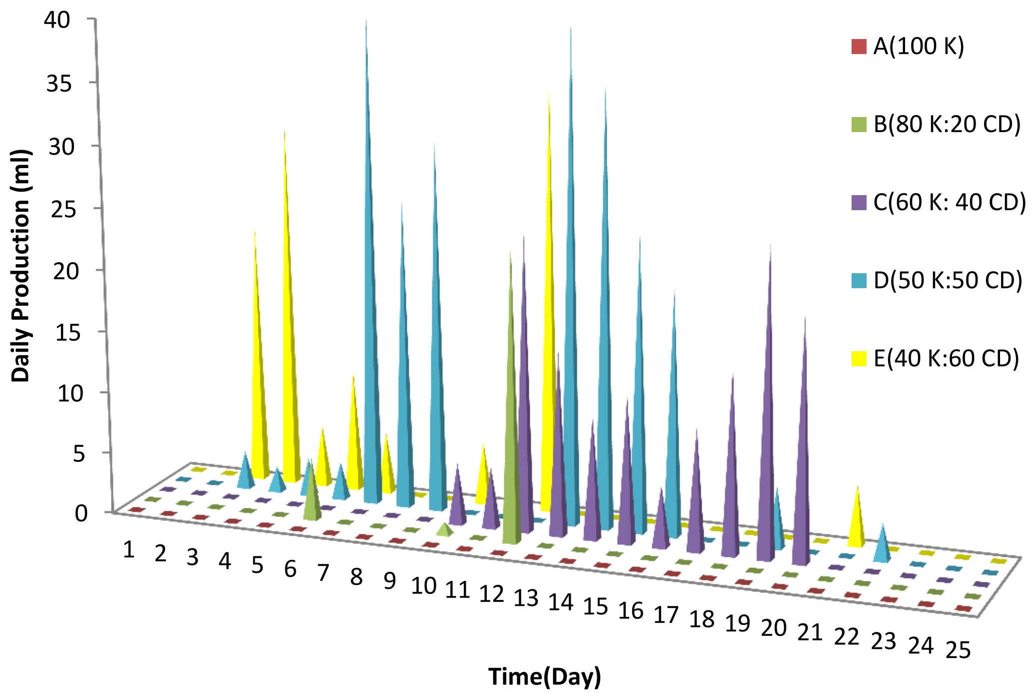


**Figure 4.1** Daily production of biogas with time interval

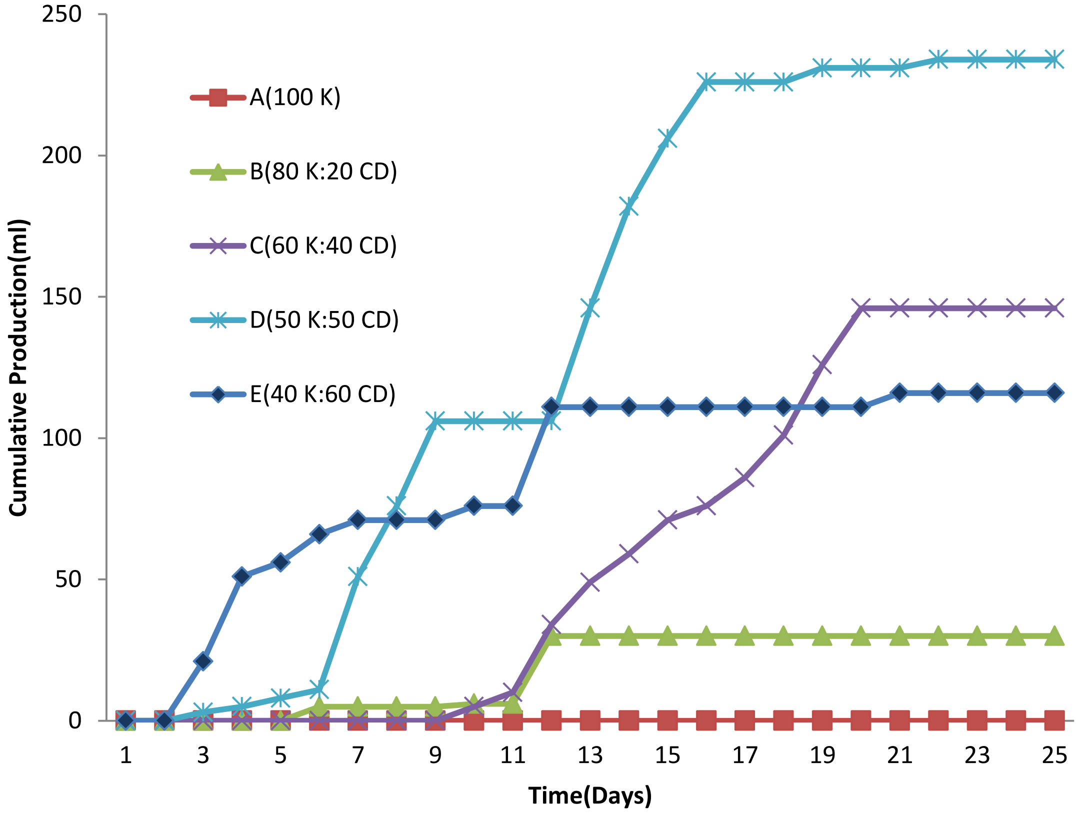


**Figure 4.2** Cumulative biogas production with time interval.

From the tables and graph shown, overall biogas production from all samples show a slow production at the beginning and at the end of observation period. From Figure 4.2, the biogas production tends to follow a sigmoid curve or S shape as it is generally occurred in batch curve. This growth curve had also been resulted by Narayani and Priya (2012), Budiyono et al.,(2010) and Budiyono (2009). As biogas production in batch production is directly proportional to the growth rate of methanogenic bacteria in anaerobic digestion, thus the resulted curve is predicted (Nopharatana et al.,2007).

Sample D (50 wt% Kundur waste,50 wt% cow dung) was observed to produce the highest cumulative quantity of biogas. As shown from Table 4.5, the biogas produced starting the 3rd day until the 9th day with total volume 106ml then followed by inactivity for three days before sudden production for the next four consequences days with cumulative of 226ml of biogas. Consequently, the biogas production increase in a stepwise fashion as the result of inactivity between them and observed with total production of 234ml and yielding 2.34ml/g TS. In the around of first $6^{th}$ day of retention time, the production is quite slow and this is due to the lag phase of the microbial growth where cells adapt themselves to the growth condition. The lag phase is the first phase that can be observed where it involved no increase in cell numbers. It may be either short or long which depend on the growth medium inside the digester. The reason to observe a period of lag phase is because the cells need to activate its metabolic pathway and undergo acclimatization process before it begins to actively growth. In the $7^{th}$ to $16^{th}$ days of digestion, the biogas production is significantly increase and is believed due to the exponential growth of methanogenic bacteria (Budiyono,2010). The log phase or exponential phase is the second phase where the bacteria started to grow and consume the substrate while releasing by products. Rapid growth of bacteria also can be observed in this phase However, the inactivity observed during the intermediate of log phase can be predicted due to the metamorphic growth of methanogens which means the microorganism undergo some changes in the growth (Dhagat,2011;Elijah et al.,2009). As there is still biogas form following the inactivity, it also can be expected that the carbon contained inside the digester did not appropriately degrade. Although it involve 1:1 ratio of substrate to inoculum, where the substrate can fully occupy the microbe available however, the substrate is believed did not yet fully converted by microbe at the initial stage of exponential phase through the anaerobic digestion. On the $17^{th}$ days onward, the production of biogas is lower and decreasing. This expected as the bacteria tend to undergo the stationary phase of growth. Stationary phase is where the metabolism slows and maintain. This also due to the lacking of nutrients and the accumulation by-products. In this stationary phase, there is very slight tendency for biogas to produce as day 19th and 20th show a very minimal production. Kundur peel is well-known for its waxy material present on the peel. This waxy-rich peel might possess a lower biodegradability tendency and causing a slower process. A proportion of 50:50 wt% of cow dung: rice chaff had shown a similar pattern for the highest biogas production curve (Vivekanandan and Kamaraj, 2011) and the result obtain for 50:50 wt % of Kundur: cow dung is comparable.

In Sample A (100 wt% Kundur waste), it can be observed that no biogas volume can be produced up to 25 days of retention time. Increasing retention time might produce biogas from this sample however it is believed that it requires too long retention time with a very minimal biogas volume production. During the digestion, the surface of the digestion slurry is covered with the waxy materials that come from the Kundur peel waste. Given the waxy materials that highly present in Sample A digester, it is believed that it is one of the resistant to enzymatic degradation and also biogas production. It is also known that the yields of biogas depend on the different characteristic of substrate used as feed materials (Calzada et al., 1984; Cuzin et al., 1992; Kalia et al.,2000; Zhang and Zhang, 1999; Momoh, 2004).The absence of inoculum to aid the degradation of the Kundur waste is the other significant factor that contributes to the zero production of biogas. The addition of inoculum to organic waste had been proved by other researchers to establish the anaerobic microflora, diminished the presence of lag phase and fostering the production of biogas (Kanwar and Guleri, 1994).

Turning to sample B (80 wt% Kundur waste: 20 wt% cow dung) and C (60 wt % Kundur waste: 40 wt % cow dung), the cumulative biogas production is 30 ml and 146 ml respectively . Sample B started to produce minimal biogas on the 6$^{th}$ day followed by few days of inactivity and a sudden burst of 24 ml on the 12$^{th}$ day. Following that, there is no biogas production observed. The stationary phase can be observed from Figure 4.1 to be on the 12$^{th}$ day which is earlier as compared to other composition. Generally, it is agreed that, the early inactivity of the digester is due to the massive decreasing of pH inside the digester. During the initial phase of biogas production, the acid-forming bacteria produce the volatile fatty acids (VFA) which cause the pH to decline. Even though the initial pH had been altered to the desired pH, the minimum composition of cow dung did not give appreciable effect as a buffering agent to the digester. Declining pH means that it inhibited the growth of methanogenic bacteria and inactivated microorganism responsible for biogas production (Cuzin et al.,1992). This can be said that the microorganism undergo the last phase which is death phase where cells have lost the ability to divide and quickly die within hours while causing by-product to stop formed.

In Sample C, the amount of cumulative biogas production show a high volume as compared in Sample B. This is due to the presence of favorably high microorganisms count in the digester that helps degrade the substrate in more efficient way. Higher composition of cow dung also is believed to maintain the pH inside the digester preventing a faster digestion failure. In Sample C, the first biogas production is observed at the 9$^{th}$ day of digestion which it retain a quite long lag phase and then producing a significant amount of biogas until 21$^{st}$ day. This is because in this composition, it consume some time for stabilization and following that the biogas production is high until no biogas production observed onwards. In a study of biogas production from co-digestion of a 60:40 wt % of cattle dung and sinew it gave maximum biogas production after a 20 days period of activity

(Pualchamy et al.,2008). Another study by Vivekanandan and Kamaraj,(2011) for biogas production at a nearly similar composition from the cow dung and rice chaff (25 wt% cow dung : 75 wt % rice chaff), the total inactivity days reported to be 5 days before an initial production on the 6$^{th}$ day for 28 ml of biogas. The reason of in Sample C it has longer inactivity is might due to the complexity in the characteristic of Kundur waste which have waxy materials on it.

As can be seen from the composition in Sample E (40 wt% Kundur waste; 60 wt % cow dung), the total biogas yield is 1.16 ml/g TS with cumulative production of 116 ml. Then by increasing the cow dung composition, the biogas produced does not exceed the total biogas produced from Sample D. This mean, the biogas produced is not fully converted by the action of cow dung itself. The usage of different composition of Kundur waste had actually effect the total cumulative production. From Figure 4.1, the production rate is highest at the 12$^{th}$ day and decreases gradually and reaches equilibrium state at the end. The reason of the early discontinuation of biogas production after the 12$^{th}$ day neglecting the minimal biogas produced for 5 ml at 21$^{st}$ day is because as the degradation process is going the excess organisms from the cow dung needed excess substrates for anaerobic digestion. Although the cow dung itself contains its own nutrients, however it is not enough for biogas to produce. Hence, this decreases the production of biogas and making the cumulative production of biogas to stop at early retention time. Gadre et al., (1990) in his report, showed that the maximum retention time for cow dung in producing biogas is around 15 days of fermentation. The variation in all the digester is might due to the presence of different composition of Kundur waste as substrate.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

In conclusion, Kundur waste is suitable to be used as substrate for biogas production. Characterization of Kundur waste mainly its peel show that it meets the necessity and suitability to be one of the feedstock for biogas production. However, anaerobic digestion of this waste alone did not show any appreciable biogas production. Adding up source of inoculum which is from cow dung slurry to aid the anaerobic digestion of Kundur waste are appropriate as experimental works resulted in production of biogas. Highest biogas yield of 2.34ml/gTS can be seen in Sample D (50 wt% Kundur waste: 50 wt% Cow dung) followed by yield of 1.46ml/gTS in sample C (60 wt% Kundur waste: 40 wt% Cow dung), 1.16mg/gTS in sample E (40 wt% Kundur waste: 60 wt% Cow dung) and 0.3ml/gTS in sample B ( 80 wt%

Kundur waste: 20 wt% Cow dung). Hence, variations of composition for the digestion of Kundur waste with cow dung as inoculum influence the total biogas yield. Therefore, biogas as one of the alternative source for energy is produced from another type of waste available today and anaerobic digestion serve as a privilege opportunity to produce an alternative fuel and most importantly managing the waste accumulation in a better way.

## 5.2 Recommendation

This research was done for a period of four months. Due to time constraints and unavailability of apparatus, this research could not be varied in various parts to perform a better testing. There are many recommendations can be done to make this research more efficient.

The first recommendation is the usage of another method in analyzing the gas composition in the sample. The method used in this research was displacement method where the amount of biogas produced will displace the water in the measuring container and the different in height was measured as volume of biogas. A more efficient method is by using gas chromatography since it will involve analytic approach to detect the concentration of gases produced. A combination of both methods is recommended due to this combination will provide better and reliable data.

Next, anaerobic digestion can be divided into many aspects such as modes of operation, types of system and also types of digester. Varying the methods of research will provide better understanding on anaerobic digestion and consequently the best system can be designed for industrialization purposes. Other than that, varying the parameters for feedstock such as the co-digestion of Kundur waste with other kind of fruit or vegetable waste also will provide more enormous information about the anaerobic digestion from agricultural waste industries.

Apart from that, the system used in this research is simple which consist of flask and tubing connected to measuring cylinder and the mixing of feed in the digester was done manually every day. So, a better system needed to be design such as a tight container equipped with jacketed vessel for maintaining temperature and impeller for mixing so that the experimental work will be much more efficient.

The effluent from the anaerobic digestion can be subject to the fertilizer testing by drying the effluent overnight and forming a pellet. The pellet are used as fertilizer and the effect of the supplying the fertilizer to plant can be investigate in order to prove that effluent from anaerobic digestion are suitable as fertilizers.

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APPENDIX A Experimental Diagram

**Figure A.1** Kundur's peel waste

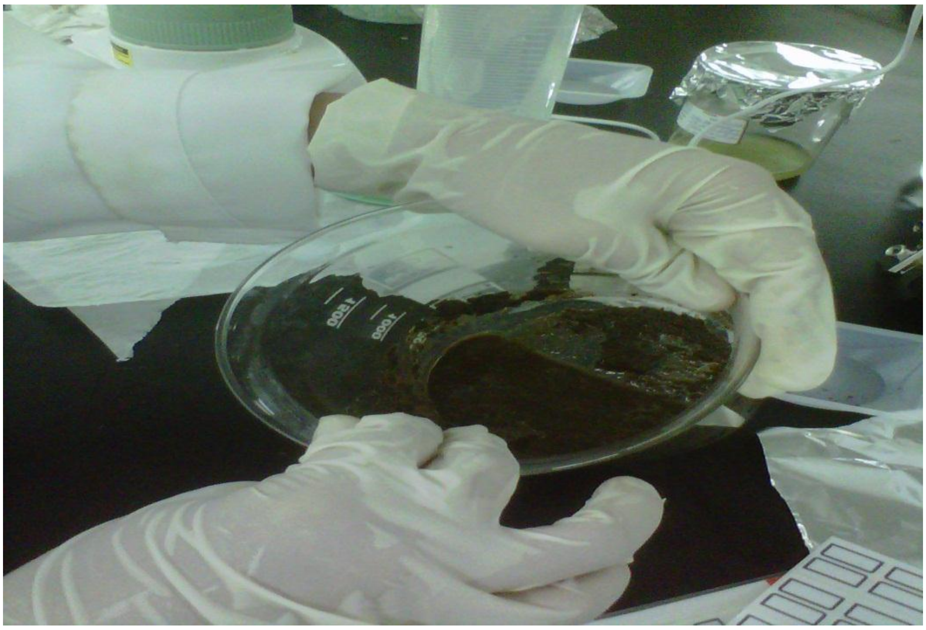

**Figure A.2** Cow dung slurry


**Figure A.3** Experimental set up in wat

# Biogas Production from *Benincasa hispida* waste

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**ABSTRACT**: Biogas production from anaerobic digestion from *Benincasa hispida* or also known as Kundur with cow dung slurry as sources of inoculum were analyzed in batch mode for five different composition under mesophilic condition, intial pH near to 7 and 10% TS. Characterization of Kundur waste and cow dung slurry for TS, TVS, initial pH, COD and $NH_3$-N were studied. Percent composition included of sample A(100wt % Kundur) , B(80 wt % Kundur,20 wt % Cow Dung), C(60 wt % Kundur, 40 wt % Cow Dung), D(50 wt % Kundur,50 wt % Cow Dung) and E(40 wt % Kundur,60 wt % Cow Dung). Sample D show a highest biogas yield 2.34ml/gTS followed by sample C (1.46ml/gTS) and sample E (1.16ml/gTS) and sample B (0.3ml/gTS). Sample A showed no biogas production. Cow dung and Kundur composition influenced the total biogas production.

**Key words:** Anaerobic Digestion, Kundur waste, Cattle Dung, Biogas, Composition

## 1. INTRODUCTION

Waste is defined as the eliminated or discarded substance or materials or by-product from the completion of a process as they no longer useful. During the olden time, the waste generated is low and bring less environmental effects occurs as the human population and the activities of industrialization is minimal. However, abundant of waste nowadays from various industry such as agricultural, forestry, municipal market waste, food processing industries, etc., constitute a large and serious environmental burden to the places all over the world. They generate unpleasant odour to the surrounding, attracting pest such as flies and contribute to an uneconomically way of living. In common practice in organic solid waste management from the agriculture sectors and livestock farm, the wastes commonly are transported to the landfill to be thrown away. Other than that, incineration is the other method where the process of combustion of the organic matter into ash takes place. However, as according to the Ministry of Housing and Local Government (MHLG), the majority of all 112 landfills in Malaysia are almost at its full capacity. On the other hand, incineration process releases odor emissions and bad for human health. Alternatively, there is one green way to converting the wastes into something valuable for human being which is anaerobic digestion. Anaerobic treatment encompasses of decomposition of organic material in the absence oxygen to produce gases such as methane, carbon dioxide, ammonia and traces of other gases and organic acids of low molecular weight (Abu Bakar and Ismail, 2012)[1].

Fruits waste have much easily digestible carbohydrate and this represent the potential substrate or feed for production of biogas such as hydrogen ($H_2$), carbon dioxide ($CO_2$) and methane ($CH_4$) through anaerobic digestion (Zajic et al., 1979)[2]. In recent years, researchers have been attracted to study the anaerobic treatment of fruit wastes and other types of biomass to generate biogas such as $H_2$ and $CH_4$ because it involve treating the wastes into more stabilized form and generate useful products. The usage of Kundur waste as substrate for biogas production could lead to a new degree of information that wastes from this fruit also suitable as a biomass for yielding biogas. Thus, economical use is developed from another type of wastes present nowadays which is biogas that can be used for energy and also electricity. Apart from that, this process not only provides renewable sources of energy that can be used as electricity or cooking but produce excellent organic manure (Mallick et al., 2009)[3].

## 2. METHODOLOGY

### 2.1 Design Method

The study was conducted by varying the proportion of biomass (Kundur waste) and source of inoculum (cow dung) while amount of total solid, temperature, initial pH and retention time were kept constant.The ratio of amount of total solid to water in each digester also similar.

## 2.2 Sample collection

Fruit peel waste from Kundur were collected from Warisan Kundur Resources, Pekan, Pahang. Hand sorting was done to segregate unwanted materials (plastic covers, rocks, etc.). Segregated waste was stored in 4$^{o}$C until further used. The waste were shredded to small particles and homogenized to facilitates digestion (Bouallagi et al., 2005)[4]. Cow dung were collected from a private farm in Felda Lepar Hilir, Gambang, Pahang and kept in room temperature until further used. Cow dung were crushed manually with pestle and mortar to ensure homogeneity (Iyagba et al., 2009)[5].

## 2.3 Analytical determination

Waste from Kundur and cow dung were characterized to determine its Total Solid( TS), Total Volatile Solid (TVS), Chemical Oxygen Demand (COD), Ammonia-Nitrogen ($NH_3$-N), and pH using the standard method.

## 2.4 Apparatus set-up

All apparatus were properly washed with soap solution and allowed to dry by standing overnight in the laboratory. Five 2000 ml of flask were used in this experiment. Each contained different composition based on weight percent basis and connected to into an inverted measuring cylinder by means of connecting tube. The inverted measuring cylinder was filled with water and inserted into a beaker filled with water.

Thus the biogas produced in the headspace of the digester passed through the connecting tube to the measuring cylinder containing solution. The pressure of biogas produced cause a displacement of the water solution. Difference in volume before the water displacement occurs and after displacement has taken place is measured as the volume of biogas produced**.**

## 2.5 Parameters of biogas production and their selected operating conditions

The research was carried out under mesophilic temperature that ranged between 30$^{o}$C to 37$^{o}$C. Temperature maintained by using water bath. Initial pH values for samples A,B,C,D and E are 7.02, 7.18, 7.23, 7.35 and 7.47 which all fall within the pH range for biogas production. In order to adjust the desired initial pH, different amounts of hydrochloric acid (0.1N HCl) and sodium hydroxide (0.1N NaOH) were used (Cubilos et al,2010)[6].

## 2.6 Water content

The water content for each sample was determined using the recommendation for better biogas production as reported by Igoni et al.,(2008)[7] and Sadaka et al., (2003)[8] that is a total solid of 10% in the fermentation slurry. This was the basis for the determination of the amount of water to be added for any given mass of total solid. Hence, there would be the equal proportion solid to water to all the samples.

## 2.7 Sample proportions

For the purpose of this research, there were six x:y proportions aimed at investigating the efficiency of Kundur waste in biogas production. The six proportions were as follow: A; 100:0, B; 80:20, C; 60:40, D; 50:50, E; 40:60, and F; 20:80, Kundur waste: cow dung on weight percent basis as in Table 1.

Table-1. Proportion of substrate and inoculum

| Samples (Proportion) | % of K | % of CD |
|---|---|---|
| A | 100 | 0 |
| B | 80 | 20 |
| C | 60 | 40 |
| D | 50 | 50 |
| E | 40 | 60 |

K represent Kundur waste; CD represent cow dung

## 2.8 Fermentation slurry

Preparation of fermentation slurry was done by the addition and also mixing of solid content with equivalent amount of water needed. This mixture was the sample contained in the digester.

# 3. RESULT AND DISCUSSION

The average composition of Kundur waste and cow dung is presented in Table 2.

Table-2. Composition of cow dung and Kundur waste

| Parameters | Cow dung | Kundur waste |
|---|---|---|
| TS,% | 68.5 | 64.09 |
| VS,% | 79.2 | 93.17 |
| COD(mg/l) | 6900 | 21330 |
| $NH_3$-N(mg/l) | 680 | 14.7 |
| pH | 7.1 | 4.34 |

The value of VS and COD for Kundur waste is quite high. High value of VS and COD are favorable for anaerobic digestion (Tewelde,2012)[9]. However, there is no literature found for characterization of Kundur waste to be compared. The pH for Kundur waste is slightly acidic which is not satisfactory as feed for biogas generation however it is neutralized easily by the addition of cow dung which tend to be more alkaline or by addition of 0.1N NaOH. Manure digesters mainly from cow dung possess a great buffer capacity and high ammonia content than other waste which means it required more acid to reduce the digester's pH, consequently making pH stable around initial value while VFA concentration can be tolerated before pH drop (Pind et al., 2003)[10].

Biogas production with time from samples A,B,C,D and E are shown in Figure 1 and 2. Overall biogas production from all samples shows a slow production at the beginning and at the end of observation period. The biogas production tends to follow a sigmoid curve or S shape as it is generally occurred in batch curve. This growth curve had also been resulted by Narayani and Priya (2012)[11], Budiyono et al.,(2010)[12] and Budiyono et al.,(2009)[13]. As biogas production in batch production is directly proportional to the growth rate of methanogenic bacteria in anaerobic digestion, thus the resulted curve is predicted (Nopharatana et al.,2007)[14].

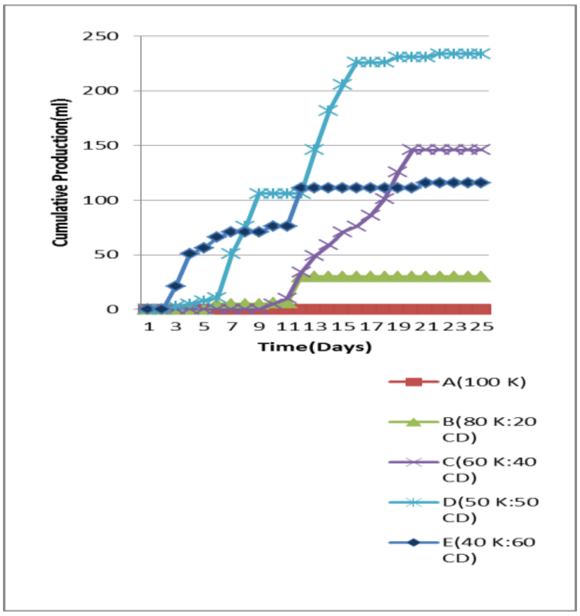


Figure-1. Cumulative biogas production

Sample D (50 wt% Kundur waste,50 wt% cow dung) was observed to produce the highest cumulative quantity of biogas. From Figure 2, the biogas produced starting the 3rd day until the 9th day with total volume 106ml then followed by inactivity for three days before sudden production for the next four consequences days with cumulative of 226ml of biogas. Consequently, the biogas production increase in a stepwise fashion as the result of inactivity between them and observed with total production of 234ml and yielding 2.34ml/g TS. In the around of first 6th day of retention time, the production is quite slow and this is due to the lag phase of the microbial growth where cells adapt themselves to the growth condition. From Figure 2, in the 7th to 16th days of digestion, the biogas production is significantly increase and is believed due to the exponential growth of methanogenic bacteria (Budiyono et al., 2010)[15]. However, the inactivity observed during the intermediate of log phase can be predicted due to the metamorphic growth of methanogens which means the microorganism undergo some changes in the growth (Dhagat,2011;Elijah et al.,2009)[16][17]. As there is still biogas form following the inactivity, it also can be expected that the carbon contained inside the digester did not appropriately degrade. Although it involve 1:1 ratio of substrate to inoculum, where the substrate can fully occupy the microbe available however, the substrate is believed did not yet fully converted by microbe at the initial stage of exponential phase through the anaerobic digestion. On the 17th days onward, the production of biogas is decreasing. This expected as the bacteria tend to undergo the stationary phase of growth. Stationary phase is where the metabolism slows and maintain. In this stationary phase, there is very slight tendency for biogas to produce as day 19th and 20th show a very minimal production. Kundur peel is well-known for its waxy material present on the peel. This waxy-rich peel might possess a lower biodegradability tendency and causing a slower process. A proportion of 50:50 wt% of cow dung: rice chaff had shown a similar pattern for the highest biogas production curve (Vivekanandan and Kamaraj, 2011)[18] and the result obtain for 50:50 wt % of Kundur: cow dung is comparable.

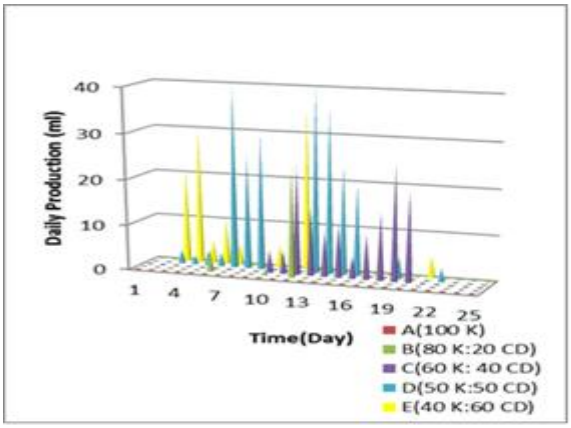


Figure-2. Daily biogas production

In Sample A (100 wt% Kundur waste), it can be observed that no biogas volume can be produced up to 25 days of retention time. Increasing retention time might produce very minimum biogas from this sample however it is believed that it requires too long retention time with a very minimal biogas volume production. Given the waxy materials that highly present in Sample A digester, it is believed that it is one of the resistant to enzymatic degradation and also biogas production.

Turning to sample B (80 wt% Kundur waste: 20 wt% cow dung), the cumulative biogas production is 30 ml. The stationary phase here can be observed from the 12$^{th}$ day which is earlier as compared to other composition. Generally, it is agreed that, the early inactivity of the digester is due to the massive decreasing of pH inside the digester.

In Sample C (60 wt% Kundur waste:40 wt% cow dung), the amount of cumulative biogas production show a high volume as compared in Sample B. This is due to the presence of favorably high microorganisms count in the digester that helps degrade the substrate in more efficient way. Higher composition of cow dung also is believed to maintain the pH inside the digester preventing a faster digestion failure. In Sample C, the first biogas production is observed at the 9$^{th}$ day of digestion which it retain a quite long lag phase and then producing a significant amount of biogas until 21$^{st}$ day. In a study of biogas production from co-digestion of a 60:40 wt % of cattle dung and sinew it gave maximum biogas production after a 20 days period of activity (Pualchamy et al.,2008)[19]. As can be seen from the composition in Sample E (40 wt% Kundur waste; 60 wt % cow dung), the total biogas yield is 1.16 ml/g TS with cumulative production of 116 ml. By increasing the cow dung composition, the biogas produced does not exceed the total biogas produced from Sample D. This mean, the biogas produced is not fully converted by the action of microorganism in the cow dung itself. The usage of different composition of Kundur waste had actually effect the total cumulative production. Gadre et al., (1990)[20] in his report, showed that the maximum retention time for cow dung in producing biogas is around 15 days of fermentation. Comparing with the data from all digesters, different retention time is shown. The variation in all the digester is might due to the presence of different composition of Kundur waste as substrate.

## 4. CONCLUSION

The outcome of this study suggests that Kundur waste can produce biogas only if supplied with source of microorganism that helps the degradation in anaerobic digestion. Characterization of Kundur waste and cow dung show that both are suitable to be used in biogas production. In this case, cow dung serves as one of the good source of microorganism for biogas production. Kundur waste alone did not show any contribution in biogas genration. The residue from the digestion can be used as the fertilizer.

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