ANAEROBIC CO-DIGESTION OF PALM OIL MILL EFFLUENT WITH COW MANURE FOR BIOGAS PRODUCTION

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To my beloved Parent, and to my Wife and Children

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ABSTRACT

Palm oil mill effluent and cow manure are excellent substrates for biogas production in anaerobic digesters though the biogas yield from a single substrate is not high. However, mixing palm oil mill effluent with cow manure (CM) or any other kind of waste materials in co-digestion can optimize the production of biogas. In this research work, the biogas potentials from palm oil mill effluent and cow manure as a single substrate as well as co-substrates was investigated. In addition the effect of chemical oxygen demand (COD) and volatile solids (VS) removal efficiencies towards biogas production and its methane content was also investigated. Anaerobic batch digesters were used for the digestion and were operated at room temperature (28^{o}C to 34°C) for 21 days. The digesters were operated at different POME – CM compositions, they are; 100% POME, 100% C.M, 60% POME + 40% C.M, 70% POME +30% CM and 80% POME + 20% CM. Approximately 717 mL, 443 mL, 864 mL, 1875 mL and 1504 mL of the biogas yields could be obtained, respectively, after 21 days of digestion. Average methane content of the biogas was 44.17%, 40.59%, 46.12%, 61.13% and 50.56%, respectively. Maximum cumulative biogas production after 21 days of digestion was obtained as 1875ml with maximum methane content as 61.13% in the mixture containing 70% POME + 30% CM. Co-digestion of 70% POME + 30% CM improved the removal efficiency up to 75% COD & 68% VS with its corresponding methane content of 61.13% which has been recognized as the optimum for biogas production as well as methane content. Biogas yield was improved by 21%, 162% and 110% v/v using the co-digestion as compared to the digestion of POME alone and 95%, 323% and 240% v/v as compared to the digestion of CM alone respectively. These results showed that biogas and its methane content production can be enhanced efficiently through co-digestion process.

ABSTRAK

Sisa industri minyak sawit dan sisa buangan pepejal lembu adalah unsur yang baik untuk penghasilan biogas dalam proses tindak balas anaerobik walaupun biogas yang terhasil daripada unsur tunggal adalah tidak tinggi. Walau bagaimanapun, mencampurkan sisa industri minyak sawit dengan sisa buangan pepejal lembu atau lain-lain bahan buangan dalam tindak balas bersama dapat mengoptimumkan penghasilan biogas. Dalam kajian ini, potensi biogas terhasil daripada sisa industri minyak sawit dan sisa buangan pepejal lembu sebagai unsur tunggal dan unsur bersama adalah disiasat. Selain itu, kesan permintaan oksigen kimia (COD) dan keberkesanan pepejal mudah teruap terhadap penghasilan biogas dan kandungan metana juga disiasat. Penghadam berperingkat anaerobik digunakan untuk tindak balas dan dijalankan pada suhu bilik (28°C to 34°C) untuk 21 hari. Penghadam ini dijalankan pada nisbah campuran berbeza, iaitu ; 100% POME, 100% CM, 60% POME + 40% CM, 70% POME +30% CM dan80% POME + 20% CM. Dianggarkan 717 ml, 443 ml, 864 ml, 1875 ml and 1504 ml penghasilan biogas telah diperolehi selepas 21 hari tindak balas. Purata kandungan metana biogas adalah masing-masing 44.17%, 40.59%, 46.12%, 61.13% and 50.56%. Penghasilan biogas kumulatif maksimum selepas 21 hari tindak balas adalah 1875 ml dengan kandungan metana maksimum adalah 61.13% dalam campuran mengandungi 70% POME + 30% CM. tindak balas bersama dengan 70% POME + 30% CM membaiki keberkesanan peralihan sehingga 75% COD & 68% VS dengan kandungan metana 61.13% yang dikenal pasti sebagai penghasilan biogas dan juga kandungan methana yang optimum. Penghasilan biogas telah dibaiki sebanyak 21%, 162% dan 110% v/v menggunakan tindak balas bersama berbanding dengan CM sahaja. Keputusan ini menunjukkan kandungan biogas dan metana dapat dipertingkatkan dengan berkesan dengan proses tindak balas bersama.

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LIST OF ABBREVIATIONS

ASABE		American Society of Agricultural and Biological Engineers
%	-	Percent
^{o}C	-	Degree Celsius
±	-	More or Less
BOD	-	Biochemical Oxygen Demand
H_2	-	Hydrogen
H_2O	-	Water
H_2S	-	Hydrogen Sulphite
CH_3	-	Ammonia
CH_4	-	Methane
cm	-	Centimeter
CM	-	Cow Manure
CO	-	Carbon Monoxide
CO_2	-	Carbon Dioxide
COD	-	Chemical Oxygen Demand
FID	-	Flame – Ionization Detector

g	-	Gram
GC-TCD	-	Gas Chromatography- Thermal Conductivity Detector
Kg	-	Kilogram
L	-	Liter
m^3	-	Cubic Meter
mg	-	Milligram
mL	-	Milliliter
N_2	-	Nitrogen
PE	-	Polyethylene
POME	-	Palm Oil Mill Effluent
TS	-	Total Solids
TSS	-	Total Suspended Solids
VS	-	Volatile Solids
V_{CM}	-	Volume of Cow Manure
V_{POME}	-	Volume of Palm Oil Mill Effluent

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CHAPTER 1

INTRODUCTION

1.1 Background

Inadequate supply of fossil fuel and negative environmental impact associated with its depletion at faster rate due to total dependence on it globally and yet it is non-renewable has improved the people interest in exploring for alternate source of cleaner energy such as biogas (energy from plant/animal origin) resources which are more sustainable, affordable and eco-friendly. Biogas is a mixture of methane (CH_4), carbon dioxide (CO_2), and some trace gases which generated from biomass or organic materials under anaerobic conditions (Solomon and Lora, 2009).

Biogas generation depends on several operating parameters namely total solid content, temperature, pH, retention time, carbon to nitrogen ratio, mixing and volatile solids content which needs proper monitoring and control to achieve maximum yield of biogas. Due to inherent complexity of anaerobic digestion process and its wide applications as well as the peculiarity and nature of different substrates involved; it is not possible to ascertain the optimum value for the parameters for all situations and substrates. This makes the research in biogas yield a very wide area of study. Feed stocks for biogas generation include crop residues, organic wastes, animal manure, kitchen waste and algae known as biomass.

Biomass are organic matter available on a renewable basis, including forest and mill residues, wood wastes, agricultural crops and wastes, animal wastes and municipal solid wastes. Figure 1.1 shows how biomass is converted into bio-renewable energy. Biomass is a renewable energy source of solar energy and has been found as a reliable substitute to fossil fuel. However, in direct energy conversion to other forms, solar energy is less efficient in the process. The solar energy is absorbed by green plant tissue through the process of photosynthesis to provide energy. This process enhances formation of carbohydrates in the plant tissue and reduction of carbon dioxide in the atmosphere. The formed carbohydrates are then utilized as energy sources and raw materials for all other synthetic reaction in the plant. The potential sources for bio-energy include; industrial organic waste, energy crops, municipal solid waste, cellulose rich biomass, by-product of biodiesel and ethanol, seaweed and algae (water based), and agricultural waste as shown in Fig 1.1

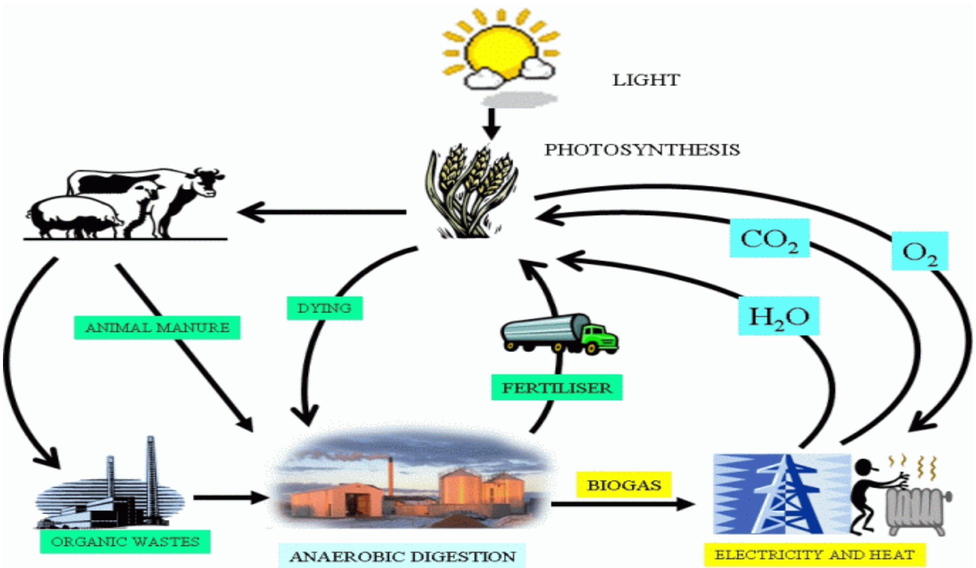

Figure 1.1 Conversion of biomass to renewable energy (Lantz *et al*., 2007)

There is a negative issue associated with the emissions from internal combustion engines using fossil fuels that leads to pollution of the global environment. In addition these emissions cause soil pollution, air pollution, acid rain as well as global warming. There is no net addition of carbon dioxide to the environment by plants since their emissions were used in photosynthesis and have low sulfur content. Therefore, bio-fuels are more environmentally than fossil fuel. They are oxygenated fuels (10% oxygen content) and so will burn properly and contribute to clean air approaches.

Many countries such as United States, Sweden, Denmark and many others today are embarking on bio-fuel production (biogas) which emits zero carbon dioxide (CO_2) to the environment when burn and contribute to clean air approaches as mention earlier (Ituen *et al.,* 2009). There are many advantages of biogas over other alternative renewable energy, namely. It can produce at any time when needed and be easily stored. It can be used the same application as natural gas. It can also be utilized in many energy services. For example in Sweden biogas is primarily used for heating, vehicle fuel and electricity/power generation (Svensson *et al.,* 2008). Also in United States, bio-fuel is moving towards replacing fossil fuels in the transport sector, such as bio-diesel can be blended with diesel at a certain proportion for anti-environmental pollution (Ituen *et al*., 2009).

"According to the Kyoto protocols, many of the industrialized nations need to reduce their carbon dioxide emissions by 5% by 2010 as compared with the 1990 level, while the further decrease will be compulsory in the long term" (Tricase and Lombardi, 2009).

However, one method of approach to overcome the problem of global energy dependent on imported energy sources and the carbon dioxide emissions levels is to substitute conventional fuels (fossil) completely or partially with carbon dioxide neutral bio-fuels such as biogas through development of the "cleaner" technologies that generate alternative fuel with the following advantages namely use it frequently without depleting it, no contributing towards global warming, no pollution emissions, low cost applications when counting all costs, and saving health and its costs.

Deublein and Steinhauser, (2008) stated that in the near future inadequate supply of fossil fuel from oil producing countries would influence many dependent countries to switch to bio-energy which is obtainable. In a related report by (Demirel and Scherer, 2008) that energy sources are being split into three categories namely fossil fuel, renewable sources and nuclear sources. The renewable energy sources are solar, wind, hydroelectric, biomass and geothermal power.

The palm oil industry in Malaysia produces more than enough biomass for its heating and power needs, and in fact causing disposal problem for the industry. It is estimated in the year 2005, over 50 million tons of biomass generated from the industry and this will continuously increase due to the world demand of palm oil. Among the biomass generated only palm oil mill effluent has not been re-used commercially. However, proper handling of POME could be beneficial by converting it into valuable products such as biogas (Hassan *et al.*, 2004).

POME need to be treated before released to the environment due its high constituent of BOD with an average value of 25,000 mg/L and Chemical Oxygen Demand (COD) with an average value of 50,000 mg/L which contributes towards water and air pollution. In a related report by Ahmad and Chang (2009) around 1,095 million kg of BOD discharged in year 2009 as a result of improper treatment of POME and causes high rate of air and water pollution during the period. Wu *et al.,* (2007) also reported that Malaysian palm oil industry has been known as one among industries that causes the highest pollution load into the river.

Cow manure is a superb substrate for producing biogas when co-digested with other sorts of spend for example organic industrial waste, household waste and sewage sludge despite the fact that its methane yield as a single substrate is low also it takes longer retention time before manufacture of biogas (IEA, 2005). The reason why because of its low methane yield and lengthy retention time like a single substrate are its high-water content and fraction of fiber (lignocellulose) hard to biodegrades unless of course pretreated (Angelidaki and Ellegaard, 2003). However, cow manure can serve as a great “carrier” substrate throughout the mixed digestion of wastes and enables anaerobic digestion of concentrated industrial waste, which may be a challenge to deal with separately (Lehtom¨aki et al., 2007). This viability of manure for use as “carrier” substrate is due to its high-water content, which behave as solvent for dry spend, its high loading capacity that regulates the optimum pH within the reactor, and also the higher level of nutrient, essential for optimal bacteria growth (Tang et al., 2008). Anaerobic co-digestion of cow manure with any other sorts of spend gives roughly 63% of biogas. The benefits of co-digesting cow manure along with other sorts of spend happen to be reported in various scientific studies. Angelidaki and Ellegaard (2003) reported it elevated in biogas yield because of co-digestion of cow manure along with spend within the anaerobic digestion process due to nutrient content in cow manure and it is greater loading capacity. Today, co-digesting of various substrates has turned into a standard technology in many of the European nations and in Asia and USA.

In the present study, co-digesting of cow manure with POME may be identified as the new alternative method of improving the efficiency of the reactor as well as the biogas yield. In case of mono-digestion of POME, providing of missing nutrient such as nitrogen like-nutrient also micronutrients and other trace elements are quite costly. Therefore, co-digesting of cow manure with POME will reduce the cost of providing the missing nutrient required by microorganism in the reactor for successful operation of anaerobic digester. Cow manure which is rich in nutrient is capable of supplementing the missing nutrient content into the POME, such as nitrogen.

1.2 Problem Statement

Anaerobic mono-digestion of animal manure and POME has been widely researched and demonstrated. In Malaysia, there is no known anaerobic digestion of cow manure is found. However, based on the data analysis from the literatures, the economics of dairy digesters are discouraging because of the low biodegradability and low yield of biogas from dairy manure, as compared to different types of organic wastes such as food waste. Co-digesting of manure with POME or with any other waste as long as such wastes are available and can supplement the missing nutrients for the micro-organism in the digester, will increase the biogas production rate as well as improving the efficiency of the dairy digester. This study was initiated to investigate the feasibility of co-digesting of POME with cow manure for biogas production and may be identified as the new alternative method of improving the efficiency of the reactor as well as the biogas yield.

1.3 Objective

The objectives of this research work are:

1. To explore the potentials of employing co-digestion of POME and cow manure in methane production in batch culture.
2. To measure the biogas production from co-digesting POME and cow manure as compared to digesting POME and cow manure separately.

1.4 Scope of Research

1. To identify factors in anaerobic digestion that responsible for the low yield of biogas.
2. To characterize the substrates so as to determine its quality and determine the need for improvement
3. To conduct biogas generation experiment using mono-digestion and co-digestion and compare it towards biogas yield.
4. To evaluate the effect of substrate ratio towards biogas production.
5. To analyze the composition of the biogas.

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