Department of Chemical Engineering and Energy Sustainability

Faculty of Engineering

PRODUCTION OF BIOGAS FROM RICE STRAW USING PADDY RICE SOIL AS INOCULANT

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Bachelor of Engineering with Honours
(Chemical Engineering)
2015

UNIVERSITI MALAYSIA SARAWAK

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This final year projects report which entitled **"Production of Biogas from Rice Straw using Paddy Rice Soil as Inoculant"** was prepared by Mohd Rahmat bin Jalani (31245) as a partial fulfilment for the Degree of Bachelor of Chemical Engineering is hereby read and approved by:

……..... ……

DR SHANTI FARIDAH SALLEH DATE

(Supervisor)

PRODUCTION OF BIOGAS FROM RICE STRAW USING PADDY RICE SOIL AS INOCULANT

MOHD RAHMAT BIN JALANI

A dissertation submitted in partial fulfillment
of the requirement for the degree of
Bachelor of Engineering with Honours
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To my beloved family and friends

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ABSTRACT

Power generation in rural areas has been an outstanding matter in the whole world. The dependence on fossil fuel for power generation has becoming a perturbing matter since the sustainability of the fossil fuels is still a colossal issues. As an alternative to fossil fuel, biogas has become an interested matter especially for power generation purposes. This research project is intended to study on the production of biogas from the anaerobic digestion of rice straw using paddy rice soil as the microbial inoculant. The study will be focusing on the identification of available potential feedstock from the research project's location which is Kampung Assum and investigating the suitable parameters for this digestion process. The parameters for the anaerobic digestion such as the ratio of soil to water and the pH are studied in depth in this research project while the temperature is set to be in a range of 35°C to 38°C for a mesophilic condition to be achieved. The soil to water ratio of 1:1, 1:1.5, 1:2, 1.5:1, and 2:1 have been done in parallel manner in fabricated biodigesters and incubator where 1:2 soil to water has produce the highest yield among all other ratios used. While for the pH study, a control experiment has been conducted intended for the study of the effect of pH on the digestion. Resulting from this study, the desirable initial pH for anaerobic digestion must be exceeding the pH value of 5.5. The combustibility test has shown a positive result where the gas produced is combusted with a blue flame without any foul smell. Hence, the gas produced from the anaerobic digestion of rice straw can be considered as biogas.

Keywords: *Anaerobic digestion, rice straw, microbial inoculant*

ABSTRAK

Penjanaan tenaga terutamanya elektrik telah menjadi suatu tumpuan yang menarik minat seluruh dunia. Tahap keterbergantungan terhadap bahan api fosil untuk penjanaan kuasa adalah satu isu yang belum lagi dirungkaikan. Jadi, biogas menjadi salah satu alternatif untuk menggantikan bahan api fosil terutamanya dalam penjanaan kuasa. Projek kajian ini adalah untuk mempelajari secara mendalam terhadap penjanaan biogas daripada proses penghadaman batang padi secara anerobik dengan kehadiran tanah padi sebagai pembiak mirob. Kajian ini bertujuan untuk mengenal pasti bahan mentah yang berpotensi terdapat di lokasi kajian iaitu Kampun Assum. Disamping itu, parameter yang sesuai untuk menjalankan proses penghadaman ini turut dikaji. Antara parameter yang dikaji dalam kajian ini adalah nisbah tanah kepada air dan nilai pH yang bakal digunakan. Manakala, suhu yang ditetapkan untuk proses ini adalah dalam kadaran dari 35°C kepada 38°C untuk memastikan keadaan *mesophilic* tercapai. Nisbah yang digunakan adalah of 1:1, 1:1.5, 1:2, 1.5:1, dan 2:1 dimana eksperimen ini dijalankan secara serentak meggunakan bekas penghadam dan inkubator yang sebelumnya telah direka. Kajian ini telah menunjukkan nisbah 2:1 telah menghasilkan biogas yang paling banyak di antara eksperimen-eksperimen yang lain. Selain itu, satu set eksperimen yang bertindak sebagai set *control* yang akan digunakan di dalam kajian kesan nilai pH terhadap proses penghadaman. Hasil dari kajian ini, nilai pH yang sesuai untuk memulakan suatu penghadaman anerobik mestilah di dalam kadaran bermula dari nilai 5.5. tambahan itu, tahap pembakaran terhadap gas yang terhasil dari proses ini telah diuji lalu menghasilkan penyalaan yang sempurna berwarna biru tanpa sebarang bau busuk dihasilkan. Maka gas yang terhasil boleh dikategorikan sebagai biogas.

Kata Kunci: *Penghadaman anerobik, batang padi, pembiak mikrob*

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ABBREVIATIONS

CH_4	-	Methane
CO_2	-	Carbon Dioxide
COD	-	Chemical Oxygen Demand
CNG	-	Compressed Natural Gas
C/N	-	Carbon to Nitrogen
H_2O	-	Water
H_2S	-	Hydrogen Sulphide
HRT	-	Hydraulic Retention Time
K	-	Potassium
LPG	-	Liquefied Petroleum Gas
N	-	Nitrogen
NH_3	-	Ammonia
OLR	-	Organic Loading Rate
P	-	Phosphorus
S	-	Sulphur
SRT	-	Solid Retention Time
TS	-	Total Solid
VFA	-	Volatile Fatty Acid
VS	-	Volatile Solid

NOMENCLATURES

°C	-	Degree Celcius
Btu	-	British Thermal Unit
cc	-	Cubic centimeter
cm	-	centimeter
cells/ml	-	Cells per milliliter
g VS/l/d	-	Grams of volatile solids per liter per day
kcal/kg	-	Kilocalorie per kilogram
kcal/m^3	-	Kilocalorie per cubic meter
kg/ha	-	Kilogram per hectare
kg/ton	-	Kilogram per ton
kg VS/m^3.d	-	Kilogram of volatile solid per cubic meter day
kWh	-	Kilowatt hour
kWh/m^3	-	Kilowatt hour per cubic meter
l/day	-	Liter per day
L/kg TS	-	Liter per kilogram of total solid
mm	-	millimeter

CHAPTER 1.0

INTRODUCTION

1.1 Background of Study

Power generation in rural areas has been an outstanding matter in unravelling of the energy conundrum in the whole world. The dependence on fossil fuel for power generation especially in terms of electrical power supply is perturbing as the sustainability of the fossil fuel for generations over is still a colossal issue worrying the mankind. On top of that, asserted by both TCRCoN (2002) and EIA (2013), the outlooks on the availability of fossil fuel for years ahead are concluding the similar proposition which is major depletion of fossil fuel throughout the world where total energy consumption grows by 12% from 95 quadrillion of Btu in 2012 to 106 quadrillion Btu in 2040. Coals, natural gas, petroleum-derived fuels, diesel and etc. are the major types of fossil fuel combusted in order to obtain the energy which utilizes for power generation purposes in Malaysia and including other countries. In 2008, according to Yusof et. al (2012), the types of fuels used for electricity generation in Malaysia is 62.8% from natural gas, followed by 27.3% for coal and only 0.1% for crude oil.

To date, there have been many studies and researches done on the matter of reducing the dependency towards fossil fuel for power generation. Renewable energy as fuel is one of the most attentive source of alternatives on energy generation where sustainability is its forte. Various forms of biomass, wind, hydro and solar are the examples of common types of renewable energies which can be implemented. However, the implementation of these alternatives are less suitable for the application in rural areas.

Rural area is defined as an open swath of land that has few homes or building where the population density is very low (NG, 2014). A rural population in a sub-district of Kuching, Kampung Assum is one of the rural areas found in Sarawak. Situated in Padawan, this site is currently inaccessible by land vehicles as there are no roads access resulting in becoming a major drawback to the residents. Consequential to the drawback therefore depriving the residents there of a few basic amenities such as electricity grid, water supply and others. Henceforth, the implementation of renewable energy as an alternative energy source has been considered profoundly in order to overcome the shortcoming in this area of study.

Masses of research projects regarding renewable energy from local available resources have been carried out so far especially its implementation in secluded or inaccessible areas. Biogas as an alternative source of energy is one of the most efficacious renewable projects that can be carried out in inaccessible villages such as Kampung Assum. According to Erickson & Fung, (1988), biogas is a combustible gas which is generally composed of 60% of methane (CH_4) and 40% of carbon dioxide (CO_2), while containing trace amounts of other gases including hydrogen sulphide (H_2S) with the ability to burn. With the properties comparable to natural gas, this biogas can be utilized for cooking purposes, illumination, burned in boilers or electricity generation in a small scale which is very suitable to be applied in this village.

One of the methods which have been used effectively in the production of biogas through anaerobic digestion or fermentation of organic waste of animal or plants or domestic usage. Fermented in a biodigester under certain range of temperature, humidity and acidity, the organic waste undergone 4 backbone stages of anaerobic fermentation which are hydrolysis, acidogenesis, acetogenesis and followed by methanogenesis respectively. These processes occurrences are due to the virtue presence of microbes and bacteria which are responsible for each respective process.

Paddy organic waste focusing on rice straw fermentation is the main focus of this study to produce useful biogas to be utilized in daily usage such as cooking and electricity generation. As the residents of Kampung Assum are relying on diesel generator for electricity generation, this project will significantly reduce their dependency on diesel as the fuel by proposing the utilization of biogas as a sustainable alternative source of energy to them. On top of producing biogas, this project will as well helping the residents in better management of the organic waste produced daily from their own kitchens. A

sustainable approach for this project is visualized in the **Figure 1.1** below instigated in a life-cycle assessment method.

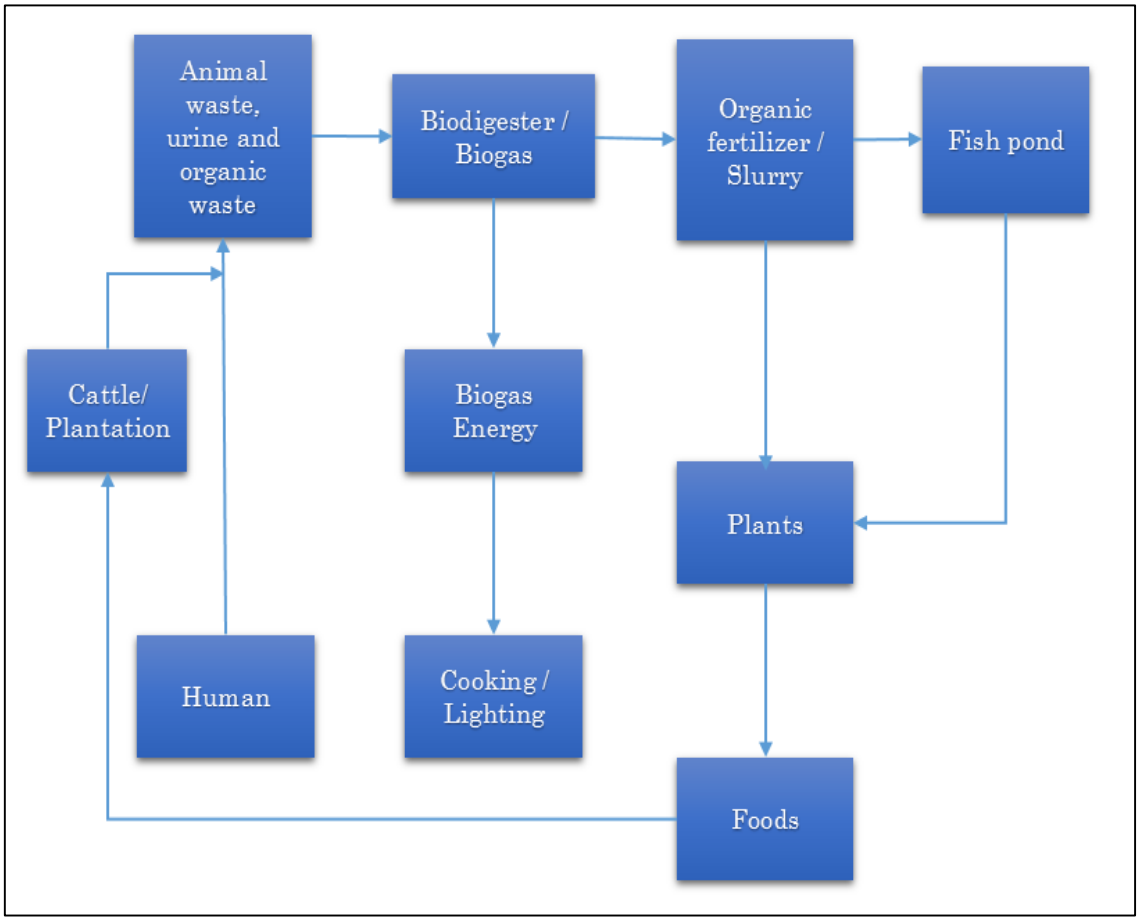

Figure 1.1: Life-cycle of biogas project (Coere, 2014).

The biogas production process is executed in a digester vessel by the breaking down of the feedstock by the bacteria and microbes responsible for the process, to which is referred as anaerobic fermentation process, as occurs in the absence of oxygen. Inorganic materials are not digested or modified in this process, hence need to be avoided as these materials are inappropriate for biogas production.

1.2 Problem Statement

The project research site, Kampung Assum is heavily depending on diesel generator as a mean of electricity generation for domestic usage daily. The supply of the fuel has been a crucial constraint to the villagers as the research project site is a rural area which is currently inaccessible by land transportation due to the absence of road connecting the village to the nearest fuel supply facilities. On top of that, the fuel prices

have been increasing throughout these year contributing in the increasing of household expenses of the residents. This might become a major hardship to the residents of Kampung Assum. Up till now, transportation is the residents' major drawback which consequently the transportation of the fuel itself. Furthermore, many of the residents in Kampung Assum are observed to plant paddy and it is noticed that there are numerous amount of paddy waste which can be utilized for the production of biogas. Henceforth, this study is proposing an alternative fuel for reducing the dependency of the residents on diesel as the main fuel for electricity generation for daily usage by utilizing the biogas produced from anaerobic digestion of rice straw. In addition, the biogas produced also can be used for cooking preferably using a biogas stove.

1.3 Aim of Research

The aim of this research is to study on the production of biogas from the anaerobic digestion of organic rice straw and the utilization of paddy rice soil as the source of microbial inoculum carried out under mesophillic conditions which will be utilized in Kampung Assum for daily power and cooking requirements.

1.4 Scope of Research

The research's scope is focusing on the application of anaerobic digestion of organic rice straw for the production of biogas in Kampung Assum. The anaerobic digestion process will be carried out under mesophillic temperature.

1.5 Objectives of Research

This research project has two main objectives which becomes the backbone of this research study. The first objective is to identify the possible feedstock for the anerobic digestion available in Kampung Assum. The type of the feedstock which will be used in the study will be determined by several factors such as the availability and suitability to the proposed project.

The second objective is to study the parameters affecting the production of biogas from anaerobic digestion of rice straw such as pH and feed ratios. Paddy rice soil is suggested to be implemented as the source of microbial inoculum of the fermentation

process which will be studied in depth in order to devise a suitable process which will be implemented in this research project.

The third objective is to study the effect of the chosen parameters on the production of biogas by varying the chosen parameter such as the feed ratios and pH.

Hence, these objectives will be a vital guidelines in conducting this research project which consequently be implemented in the research project site.

CHAPTER 2.0

LITERATURE REVIEW

2.1 Research Background

The research is intended to study the process of anaerobic digestion or also commonly called as fermentation which is utilizing the rice plantation waste specifically the rice straw used as the feedstock for the production of biogas. The research area will be Kampung Assum located in Padawan, sub-district of Kuching, Sarawak. Plantation of paddy is one of the agricultural activities conducted by the residents of this village where vast amount of agricultural waste. According to Zafar, S. (2014), the two main types of residues from the rice industry are straws and husks which both of them are possessing great potential in terms of energy generation. The biogas produced from the fermentation is intended for electricity generation; lighting purposes, cooking fuels or other suitable usage for the villagers of Kampung Assum itself.

2.2 What is Biogas?

A mixture of gases, biogas retains the ability to be combusted cleanly without soot and foul smell which is very similar to liquefied petroleum gas (LPG) or compressed natural gas (CNG). Composed of 40-70% (usually 55—65%) of methane, the rest being mostly of carbon dioxide with traces amount of other gases such as hydrogen sulphide,

biogas can be considered as a fossil fuel and therefore may be utilized in energy generation purposes (Abbasi, T. 2014: Xu, F. 2014: Culhane, T.H. 2012). Suggested by its name, biogas is a result of anaerobic degradation of organic matter (Abbasi, T. 2014). Added by Krich et al. (2005), anaerobic degradation of organic matter is primarily referring to the process anaerobic digestion of where organic matter as the substrate which undergone through a natural process of breaking down in an oxygen-free environment promoted by microbial activities in the material.

The flammability of the biogas is mainly because of the methane composition in the biogas produced from anaerobic digestion of organic matter. The calorific value of biogas is estimated to be around 6.0 - 6.5 kWh/m^3 by Vögeli et al., (2014) and approximately 5000 kcal/m^3 (5 kWh/m^3) by Abbasi, T. (2014) from their respective studies. Even though the biogas is a mixture of not only methane and carbon dioxide which yielded from the anaerobic digestion, it comprises a quite remarkable and good calorific value compared relatively to the other existing combustible fuels. The calorific of common fuels with slight differences in numerical value obtained from two sources are simplified in the Table 2.1 below:

Table 2.1 Calorific values of various fuel. Adopted from Abbasi, T., (2014), and Vögeli et al., (2014).

Fuel	**Approximate Calorific Value (kWh/$m^{3)}$**	
Biogas	5.0 [1]	6.0 - 6.5 [2]
Natural Gas	8.6 [1]	10.6 [2]
Liquefied Petroleum Gas (LPG)	10.8 [1]	26.1 [2]
Kerosene	10.3 [1]	12 [2]
Diesel	10.7 [1]	12 [2]
Reference	Abbasi, T., (2014)	Vögeli et al., (2014)

The net calorific value depends on the efficiency of the biogas burners or other applied used to process of biogas including various factors which affect the production process. For example, a gas generator can convert only 2 kWh into usable electricity while the remaining energy is emitted as heat or loss through the mechanical movements (Vögeli et al., 2014).