UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND CONSTRUCTION OF FOOD WASTE-BIOGAS SYSTEM FOR SMALL SCALE APPLICATION

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical & Manufacturing Engineering Technology (Maintenance Technology) with Honours.

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Mechanical & Manufacturing Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follow:

……………………………………

(EN. MOHAMED SAIFUL FIRDAUS BIN HUSSIN)

ABSTRAK

Biogas adalah sejenis biofuel yang dihasilkan secara semulajadi daripada penguraian sisa bahan organik melalui pencernaan anaerobik. Sisa makanan yang tidak diurus dengan baik menyebabkan kesan rumah hijau, dan isu alam sekitar. Teknologi biogas semasa tidak sesuai untuk rumah kediaman. Tujuan projek ini adalah untuk membuat tinjauan, kemudian mereka bentuk dan membina sistem biogas skala kecil. Pada mulanya, kajian menyeluruh telah dibuat melalui jurnal untuk mencari hasil terbaik dalam projek ini. Projek ini dimulakan dengan membuat tinjauan di kawasan Melaka dan Selangor diikuti dengan mewujudkan pembahagi fungsi quality, carta morfologi dan kaedah Pugh. Dengan data berwajaran, reka bentuk termasuk pemilihan bahan telah dibuat menggunakan SolidWorks. Menggunakan reka bentuk sebagai asas, prototaip sistem biogas berskala kecil telah dibuat. 4kg daging digunakan sebagai bahan mentah untuk menghasilkan biogas. Selepas dua minggu, jumlah gas diukur setiap hari selama sepuluh hari. Kadar pengeluaran biogas dan faktor-faktor yang mempengaruhi kadar pengeluaran biogas dianalisis. Penemuan menunjukkan bahawa, suhu sekitar, saiz pencerna dan jenis stok adalah faktor utama yang mempengaruhi kadar pengeluaran biogas. Untuk ujian prototaip ini, ia dapat menghasilkan purata 1 liter biogas setiap hari. Biogas yang terhasil diuji untuk kebolehan menghasilkan api dan ia menunjukkan hasil yang positif. Semua objektif projek telah telah dicapai. Kesimpulan dan cadangan telah dibuat untuk memuktamadkan projek.

ABSTRACT

Biogas is a type of biofuel that is produced naturally from decomposition of biodegradable waste through anaerobic digestion. Waste food that is not managed well causes greenhouse effect, and environmental issues. Current biogas technologies is not suitable for residential houses. The aim of this project is to do a survey, then design and construct a small scale biogas digester. Initially, a thorough study has been made through journals in order to find the best possible outcome in this project. The project was started by doing a survey in Melaka and Selangor areas followed by creating house of quality, morphological chart and Pugh method. With the weighted data, a design which includes the material selection has been made using SolidWorks. Using the design as the base, a prototype of small scale biogas digester was fabricated. 4kg of meat was used as the feedstock to generate biogas. After two weeks, the volume of gas measured every day for ten days. The rate of biogas production and the factors affecting the rate of biogas production was analysed. The findings show that, the surrounding temperature, size of the digester and the type of feedstock are the primary factors that affect the rate of biogas production. For this prototype testing, it was able to produce an average of 1 litre of biogas per day. The biogas produced was tested for the ability to create flame which resulted positively. All the objectives of the project were achieved. Conclusion and recommendation has been made to finalize the project.

DEDICATION

To my beloved parents.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ABS	-	Acrylonitrile Butadiene Styrene
AD	-	Anaerobic Digestion
AWS	-	Agricultural Waste Source
BOM	-	Bill off Material
BY	-	Biogas Yield
CD	-	Conceptual Design
CH4	-	Methane
CHP	-	Combined Heat and Power
CO2	-	Carbon Dioxide
COD	-	Chemical Oxygen Demand
C/N	-	Carbon to Nitrogen
D	-	Dimension
DM	-	Dry Matter
FA	-	Free Ammonia
FW	-	Food Waste
FAO	-	Food & Agricultural Organization
GHG	-	Green House Gas
H2O	-	Water
H2	-	Hydrogen
H2S	-	Hydrogen Sulphide
HDPE	-	High Density Poly Ethylene
HOQ	-	House of Quality
HRT	-	Hydraulic Retention Time
ISR	-	Inoculum to Substrate Ratio
KVIC	-	Khadi and Village Industries Commission
L	-	Litre

LCA	-	Life Cycle Assessment
LDPE	-	Low Density Poly Ethylene
LPG	-	Liquefied Petroleum Gas
MSW	-	Municipal Solid Waste
N	-	Number
NH3	-	Ammonia
O2	-	Oxygen
OFMSW	-	Organic Fraction of Municipal Solid Waste
OLR	-	Organic Loading Rate
P_{BG}	-	Produced Biogas
PCTFE	-	Polychlorotrifluoroethylene
PVC	-	Poly Vinyl Chloride
PW	-	Paper Waste
QFD	-	Quality Function Deployment
SBY	-	Specific Biogas Yield
SRT	-	Solid Retention Time
SWCorp	-	Solid Waste Management and Public Cleansing
TAN	-	Total Ammonia Nitrogen
TPAD	-	Temperature Phased Anaerobic Digestion
TSS	-	Total Suspended Solid
TVFA	-	Total Volatile Fatty Acid
UMSA	-	Universided Myer de San Andreas
UPVC	-	Unplastisized Poly Vinyl Chloride
UTeM	-	Universiti Teknikal Malaysia Melaka
V	-	Volume
VFA	-	Volatile Fatty Acid
VS	-	Volumetric Solution
VSS	-	Volatile Suspended Solid
WTE	-	Waste to Energy
kWh	-	kilo Watt per hour

m	-	meter
mm	-	millimetre
mm^3	-	millimetre cube
°C	-	degree Celsius
g	-	gram
kg	-	kilogram
%	-	percentage

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Biogas is a type of biofuel that is produced naturally from decomposition of biodegradable waste. Biodegradable waste is also known as organic waste which includes any organic matter that comes either from plant waste, animal waste or even human waste. These organic wastes are broken down into a mixture of preponderantly methane and carbon dioxide. The process of breaking down or decomposition of organic wastes is called “Anaerobic Digestion” (AD). In the seventeenth century, Jan Baptista Van Helmont discovered that flammable gases could develop from the decomposition of organic substances. According to Count Alessandro Volta (1776), there is a strong correlation between the quantity of decaying organic substances and the volume of incendiary gases produced. Also, Sir Humphry Davy (1808) confirmed the presence of methane in the gases produced throughout AD of cattle manure. Historical evidence shows that the AD process is one of the earliest technology because, during the tenth century BC, biogas was used to heat bath water in Assyria. In the year 1859, the first AD plant was developed in Bombay, India.

Mankind nowadays facing a very serious energy source crisis due to challenges of alleviating climate changes. The severity of the crisis further rose with the depletion of fossil energy (Mohr et al., 2015). Even though the discussion on carbon alleviation pathways and strategies have been going on for decades, fossil energy consumption and consecutive emission keep on rising. Thus, the application of waste to energy technologies such as the production of biogas is considered to be one of the finest options that meet the increasing global demand for energy consumption. The production of biogas as renewable energy decreases the dependence on fossil energy.

Additionally, these practices also contribute to efficient waste management. Petroleum, natural gas, oil, and coal are non-renewable energy that currently providing 80% of energy consumption to generate electricity that is used all around the world. The energy consumption of the world is rising by approximately 2% annually. Brazil, Thailand, China, United States of America and European countries already using biomass sources like wood as an alternative for coal and oil (Aziz et al., 2019). Out of several types of alternative renewable energy, biogas is favoured the most because it can be utilized easily and can be used directly in different applications such as fuel cells, micro-turbines, combustion generators, etc. Furthermore, biogas is also favoured because the digested waste can be used as organic fertilizer.

Despite the fact that the common utilization of alternative energies is still secondary compared to the consolidated ones, the development of sustainable sources on the world continues to expand over time. Biogas technology is one of the best options to alleviate environmental issues such as global warming and air pollution but the production of biogas may have a negative impact on the environment. Various investigations have detailed that the selection of AD may not really prompt sustainable practices (Fantin et al., 2015). Therefore, the environmental supportability of Biogas frameworks ought to be legitimately assessed by means of science and institutionalized techniques such as Life Cycle Assessment (LCA). LCA allows assessing total bioenergy generation chains through every period of its life cycle. According to Whiting and Azapagic (2014), the generated electricity and heat produced from the AD of agricultural waste leads to a drastic cutback in the highest impact group compared to non-renewable fuel alternatives. Whiting and Azapagic (2014) also condemned the emphasis on climate change and called attention to the significance of averting the issue from shifting. Diminishing the ecological effects created in climate change by expanding them to other effect classes is not an efficient way to overcome the issue in the long team.

A biogas digester is an air proof encased container intended to improve the anaerobic digestion of biodegradable waste, for example, animal manure, household wastes, sludge and the accumulation of the gas produced. There are three types of biogas digesters which are the passive system, low rate system, and high rate system. In the passive system, biogas restoration is added to the current waste treatment facility and the AD process can be controlled to a limited extent. Low rate system is where the animal manure waste coursing along the digester is the primary source of microorganism that form methane and it only vacates the digester when the designed holding time expires. Meanwhile, high rate system traps and retrain the methane-forming microorganism in the digester to improve the efficiency of biogas production. Domestic digesters have a power supply capacity below 25 kilowatt which are used to supply energy for lighting, cooking or sanitation purposes while commercial digesters have a power supply capacity from 25 to 250 kilowatt which is used for heating or electricity generation and capacity of more than 250 kilowatts for large scale installations (Demirbas, 2017).

Food and Agriculture Organization (FAO) of United Nations calculated that approximately 3/4 of entire food created for human in the world is squandered annually which led to endemic and epidemic illness. Food Waste (FW) is a vital part of Municipal Solid Waste (MSW) which encompasses restaurant waste, canteen waste, food processing waste and household food waste (Campuzano and González-Martinez, 2016). The average FW produced by a person is 250 to 300 kg per year. Ninety-seven tons of FW are wasted every year in India. Meanwhile, FW produced in Japan, United States, Europe, and China have been approximately around 22, 90, 61 and 195 metric ton respectively per year (Thi et al., 2015). FW is more reactive to AD due to its high moisture and various organic nutrient content. These conditions promote the production of methane as a promising alternative energy source. Co-digestion is concurrent digestion of multiple substrates in AD while mono-digestion is digestion of single substrate. The co-digestion basically executed to improve biogas generation, balance supplements, and control acidogenesis in the anaerobic absorption process. Due to the various benefits of co-digestion, it has better performance compared to mono-digestion (Piñas, 2018). Algapani et al. (2017) identified that the methane output by the co-digestion of sewage sludge and FW is greater in comparison to mono-digestion with FW only.

1.2 Problems Statement

The deputy chief executive officer Mohammad Diah Wahari of Solid Waste Management and Public Cleansing Corporation (SWCorp) said that Malaysians waste away 16,688 tons of food daily which is enough to feed 12 million people for three times daily. Furthermore, the amount rises by 15 to 20 percent during festivals (Sharif, 2018).

So, in order to reduce the negative impact on the environment and increase the efficiency of food waste management, a system has to be utilized to convert food waste into useful alternative energy which is the biogas. There are already lots of technologies or system that are being applied to convert organic matter into food waste in several countries. The best example is United States where they have the largest food waste digester (food waste to biogas in plant scale).

Since building a plant scale digester is not within the scope of study, the digester have to be in a domestic use level. To reduce food waste dumping in domestic level, a small scale food waste digester is necessary. There are already several existing digester types that has been used in small scale application in rural area of different countries. Most of these small scale digesters are used in poor rural areas in Africa where it is difficult to get energy supply. The biogas produced are used for their combustion for daily cooking.

The problem rises where these existing digesters are hard to be applied is Malaysia. There are three main problems to use these digesters in Malaysian households. The first problem is that the existing digesters are large in size and require considerably large space for installation. Not every household in Malaysia have the space for the installation of the digester. The second problem is the existing digesters are made to produce biogas typically from animal manure and farm wastes. The digester are installed typically close to farms where it is easier the get the wastes for biogas production. The third problem is that the digesters are very expensive. Since almost all household have a cheaper source of energy supply which is the Liquefied Petroleum Gas (LPG) to cook food daily. So, it seems as it is unnecessary to get an expensive digester when there is a cheaper source.

In order to overcome the situation, the new design of the digester has to be smaller, cheaper and easy to produce biogas using food waste as feedstock compared to the existing domestic digester. Adoption of these criteria into the design of the digester is expected to solve the issue and promote the use of digester in Malaysia

1.3 Objective of the Study

The objective of this study is:

i. To conduct a survey to identify customer requirements for a small scale biogas digester.
ii. To design a concept of small scale biogas digester.
iii. To fabricate a prototype of small scale biogas digester.

1.4 Scope of the Study

Based on the objectives, the scope of the study are highlighted as follows:

i. The survey on biogas digester will be conducted on a number of households around Melaka and Selangor.
ii. The biogas digester was designed with the aid of SOLIDWORKS, HOQ, Morphological Chart and Pugh Method.
iii. The biogas digester will be fabricated for household scale which uses waste food as the primary feedstock.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Chapter 2 will provide literature review on the biogas production along with different types of productions. This chapter also discusses anaerobic digestion, its various processes. This chapter also includes literature review on the different type of digesters. Additionally, literature review on method of survey and engineering designs are also briefed.

2.1 Biogas Production

Parsaee (2019) found that, as of late, there are two noteworthy crisis because of the developing worldwide energy consumption of non-renewable fuel source (up to 80%) which are the environmental contamination and an acceleration in energy source reduction. Accordingly, looking for clean and renewable power sources is at the highest point of the world's plan. The closest and foremost energy source that can replace fossil fuel is biomass (Pazuch et al., 2017). One of the imperative advantages of energy generation from biomass is less capital expense prerequisite contrasted with other sustainable energy sources such as wind, hydro or solar. Biogas creation from organic waste has a few pros contrasted with different alternatives such as cremation, bio-oil, and other organic items (biobutanol, biohydrogen and bioethanol), power, and biodiesel. Increased power-yielding, decreased ecological effects, and decreased capital expenditure necessities are among the points of interest. Biogas is a combustible blend when the concentration of biomethane is greater than 40%. It is delivered through a process including four phases which are hydrolysis, acetogenesis, acetogenesis, and methanogenesis utilizing a microbial consortium containing various kind of microscopic organisms. Various bacteria, including clostridium, cellulomonas, bacillus, thermomonospora, ruminococcus, baceriodes, acetovibrio, and microbispora genera, perform the hydrolysis of organic matter. Acidgenesis is primarily controlled by Lactobacillus, Streptococcus, Bacillus, and Escherichia (Christy et al., 2014). According to Nzila (2017), there are different type of genera in acetogenesis which includes acetobacterium, syntrophomonas, clostridium, sporomusa, syntrophospora, thermosyntropha, and eubacterium. Meanwhile, archeobacteria such as methanococcus, methanosarcina, and methanolobus, are responsible for methanogenesis. Parsaee (2015) also discovered that microbial groups requires specific condition for ideal biogas production such as the pH should be in the range of 6 to 7.5 and also the temperature should be in the range of 35 to 55 °C. The three essential sources for creating biogas which includes household wastes, lignocellulosic wastes, urban wastewater, and mechanical wastewater. Considering their amount around the world, the wastes of agro-industrial is high likely to contaminate the earth (De Lima and De Souza, 2014). On the off chance that these build ups are released to the environment without legitimate disposal method that may prompt environmental contamination and dangerous effects. Different issues with climate change by expanding various ozone harming substances are made by these untreated wastes. Likewise the high 'Chemical Oxygen Demand' (COD) of these untreated wastes are appropriate conditions for development of various pathogenic organisms and microorganisms (Sadh et al., 2018). The utility process of biogas production is as shown in Figure 2.1. Production of biogas is the simple method of controlling environmental pollution, supplying bio - fertilizer and producing clean and inexpensive fuel. In recent industries, biogas is being produced from various organic matters such as agricultural waste, animal manure, municipal waste, sewage sludge, green waste or food waste.