EXPLORING THE VIABILITY OF A COMPACT ANAEROBIC DIGESTION SOLUTION FOR FOOD WASTE TRANSFORMATION AND BIOGAS GENERATION

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J20A0512

A reported submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Bioindustrial Technology) with Honours

FACULTY OF BIOENGINEERING AND TECHNOLOGY

UMK

2024

DECLARATION

I declare that this thesis entitled "Exploring the Viability of a Compact Anaerobic Digestion Solution for Food Waste Transformation and Biogas Generation" is the results of my own research except as cited in the references.

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ACKNOWLEDGEMENT

With the great incredible delight to individual who make an improvement to my project with many information and practical aptitude, particular in my thesis. Thankful to my supervisor, Pm ChM Ts Dr Wong Yee Ching, that nonstop to guidance and help given to me from beginning of this FYP start until been complete.

Furthermore, my appreciation to be expended to lab assistants of UMK for helping and guiding me with lab work and machine usages. I would like to tank to all laboratory assistants involved to guiding me with the test conduct.

Likely i wanted to thank a lot my friend and classmate who motivate and help me in this journey finish my FYP. I would express my gratitude to all my friend and individual who have contribute to the successful completion to this project in any way.

ABSTRACT

The objective of this thesis is to investigate the generation of biogas from food waste, prevalent in both eateries and household kitchens. This thesis is carried out using employing laboratory-scale methods, the research aims to provide a platform for detailed observation and experimentation. The escalating disposal of food waste, that leading to the emission of harmful gases and poses a growing environmental concern, contributing to air pollution. The study primarily focuses on harnessing methane gas, derived from food waste, as a sustainable source of biogas for everyday applications, such as cooking. Gas detectors are utilized to identify gas methane presence in the study's outcomes, while pH meters analyze the acidity level during the anaerobic digestion process. The thesis outlines have three key objectives, it to identification of microorganisms involved in biogas production, exploration of the pH, temperature, and time impact on gas generation, and an examination of the quality and quantity of produced gas. The cultivation of microorganisms in food waste samples, using the streaking culture method with agar nutrient, revealed the presence of identified microbial species—Clostridium, Acetobacterium, Methanobacterium, and Propionibacterium—in a span of three to four days.

Keywords; methane gas, biogas, anaerobic process, food waste, and microorganisms.

ABSTRAK

Objektif tesis ini adalah untuk menyiasat penghasilan biogas daripada sisa makanan, yang lazim di kedua-dua kedai makan dan dapur rumah. Tesis ini dijalankan menggunakan kaedah berskala makmal, penyelidikan bertujuan untuk menyediakan platform untuk pemerhatian dan eksperimen yang terperinci. Pembuangan sisa makanan yang semakin meningkat, yang membawa kepada pelepasan gas berbahaya, menimbulkan kebimbangan alam sekitar yang semakin meningkat dan menyumbang kepada pencemaran udara. Kajian ini tertumpu terutamanya pada memanfaatkan gas metana, yang diperoleh daripada sisa makanan, sebagai sumber biogas yang mampan untuk aplikasi harian, seperti memasak. Pengesan gas digunakan untuk mengenal pasti kehadiran gas metana dalam hasil kajian, manakala meter pH menganalisis tahap keasidan semasa proses pencernaan anaerobik. Garis besar tesis mempunyai tiga objektif utama, ia untuk mengenal pasti mikroorganisma yang terlibat dalam pengeluaran biogas, penerokaan pH, suhu, dan kesan masa ke atas penjanaan gas, dan pemeriksaan kualiti dan kuantiti gas yang dihasilkan. Penanaman mikroorganisma dalam sampel sisa makanan, menggunakan kaedah kultur coretan dengan nutrien agar, mendedahkan kehadiran spesies mikrob yang dikenal pasti—Clostridium, Acetobacterium, Methanobacterium, dan Propionibacterium—dalam tempoh tiga hingga empat hari.

Kata kunci ; gas metana, biogas, anaerobic proses, sisa makanan, dan mikroorganisma.

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LIST OF SIMBOLS

% Percentage

°C Degree Celsius

L Liter

G Gram

mL Milliliter

CHAPTER 1

1.0 INTRODUCTION

1.1 Background of Study

Anaerobic digestion is a process that can provide both clean energy and environmentally sustainable management of organic wastes (Franceschi et al., 2023). This method can be used to treat organic waste, such as agricultural food that remains, food waste, sewage sludge, and energy crops. Anaerobic digestion is the result of a series of metabolic events carried out by a varied population of microorganisms such as bacteria, archaea, and protozoa. These bacteria collaborate in a step-by-step process to break down complex organic compounds into simpler ones.

In a small-scale anaerobic digestion compared to larger-scale commercial digesters, these systems typically smaller in size and have smaller processing capacity. Such as in the size and design Small-scale digesters are small in size and may be put in residential homes or small farms. They come in a variety of types, including fixed dome, floating drum, plug-flow, and batch systems. The design chosen is determined by criteria such as available area, waste type, and desired biogas production (Franceschi et al., 2023).

Biogas can be known as a different name such as It's also sometimes called marsh gas, sewer gas, compost gas and swamp gas in the US, biogas is a naturally occurring and renewable energy source produced by the decomposition of organic waste. Biogas should not be confused with 'natural' gas, which is a non-renewable energy source. (*What Is Biogas? | National Grid Group*, 2016). Biogas is seen as an alternative source due to its increased energy density and compatibility with existing transportation networks. Methane biogas has the potential to be a long-term alternative for fossil fuels, reducing greenhouse gas emissions by trapping them and preventing them from escaping into the atmosphere (Manigandan S, kumar, A, AlMallahi, & Mahmoud Elgendi, 2023).

The food solid waste that in Malaysia was produce a day that will increase the global warming effect to greenhouse in earth. The interaction of the sun energy to the greenhouse gases produces such as methane, carbon dioxide, and nitrous oxide to the atmosphere. The reaction ability happens with that gases will trap the heat at the atmosphere and reflect it to the surface that and trap the heat in the air. The gases produce from the food solid waste it can divide to the several type of gases such as methane gas, carbon dioxide, nitrogen, oxygen, ammonia, sulfate, hydrogen and other various type of gas, the percentage of the gas produce depend on the type of waste.

Organic waste has been found to comprise around 45% of total municipal solid waste (MSW) produced in Malaysia (Yong et al., 2021). Anaerobic digestion of 50% organic waste is planned to provide 3941MWh/day of electrical energy and 2500 tons of bio fertilizer per day. In terms of environmental implications, it is possible to prevent 2735 t/day of carbon dioxide (CO_2) emissions, 1128 m_2/day of landfilling area, and 481 m_3/day of leachate (e.g., “Zi Jun Yong, Mohammed J.K. Bashir, & Mohd Sayuti Hassan, 2021”).

1.2 **Problem Statement**

Natural gas is an organic resource that can be put into several uses spanning from cooking to providing heat in residential settings and producing electricity in commercially. While not renewable in nature, natural gas remains a top-tier energy option due to its practicality backed by vast reserves across different regions worldwide. Its formation process involves the gradual breakdown of fossils under immense heat exposure coupled with substantial pressure below the earth's surface for over long periods. The natural gas resources used today are deteriorating in terms of quantity due to non-renewable resources, however resources that can be used to replace of natural gas resources is by using biogas.

However, with a dense population in Malaysia produces around 36,69-tonnes of municipal solid waste (MSW) in every day, which equates to 1.17kg of garbage per person. Food waste contributed the most to MSW, followed by plastic, paper, mixed organic, wood, and other materials (352, 2022) (Ogboo Chikere Aja & Al-Kayiem, 2013). This course would cover the negative impacts of poor waste management, such as air, water, soil pollution, greenhouse gas emissions, and the effects on ecosystems and public health, the unproper to maintain waste from the economic waste such as industrial waste, electronic waste and agriculture waste can leach to metal environment. Malaysian MSW is mostly created of 45% food waste, 24% plastic, 7% paper products, 6%, 4% wood, and 3% glass, and has a moisture level of 52-66%. Currently, 80-95% of collected MSW is landfilled, with the remaining 5% recycled (Ogboo Chikere Aja & Al-Kayiem, 2013).

The increase in the amount of waste makes the land use increase and also in maintenance costs the waste site. Malaysia's waste management is an ongoing economic and environmental issue.

More than 80% of Malaysian solid waste is currently disposed of in landfills and dumpsites. As a result, Malaysia faces an urgent need to transition to sustainable solid waste management and, resource recovery from organic solid waste (e.g., "Zi Jun Yong, Mohammed J.K. Bashir, & Mohd Sayuti Hassan, 2021"). Due to the increasing amount of waste every day, it can produce to other product such as bio products such as biogas through anaerobic processes, which are the processes not involving air.

1.3 Objective

1. To identify specific microbes present in food waste in optimizing biogas production at anaerobic process.

2. To study of effect pH, temperature and time to the gas production in the anaerobic process.

3. To study the quality and quantity gas produce from food waste as they feed stock.

1.4 Scope of Study

This study aims to focus on the biogas production in lab scale using food solid waste in Malaysia. Raw material use in this study is food waste, that was be collected from surround the campus University Malaysia Kelantan campus Jeli's. In other the optimum of the study, several parameters will be use in this experiment for the production of the biogas such as different in temperature before and after the process, the different of the pH like alkaline natural, and acid reaction of time used. From the raw material use in this experiment will be put in the digester tank with anaerobic process, this process makes the microorganisms digest the feedstock to produce gas. The gas will be collected from measuring cylinder by water displacement technique, this method can be used to calculate how many gasses was produce from the digester process. Each flask using in this experiment use pipe to flow the gas from digester tank to gas store. The methane gas detector will be use in study about the quality and the quantity gas that was produce from the anaerobic co-digest process.

To study the pH, temperature and time use in this experiment would like to use a software that can run and calculate the data which is Response Surface Methodology (RSM) to identify the optimization parameter use in this experiment and compare with the actual run experiment.

1.5 **Significant of Study**

The research of potential for renewable energy generation and reducing reliance on finite fossil fuels. Renewable energy generation of biogas is a renewable energy source that is created from food waste. It mostly includes methane (CH_4) and carbon dioxide (CO_2), which can be used to replace fossil fuels. Biogas may be used to generate power, heat, or as a transportation fuel, so contributing to a more sustainable and cleaner energy mix. In comparison to fossil fuels, which are finite and contribute to climate change, these sources are sustainable and have a low environmental effect. Malaysia is mainly dependent on fossil fuels for energy, making up 78.0% of total energy consumption, while water power and renewable energy provide 18.0% and 4.0%, respectively (WorldData.info (2020). Base on the (Lead & Jain, n.d.), Malaysia has a population of over 31 million people generating sewage as well as food waste. These two sources of organic matter have the potential of generation 285 MW of energy and nutrients, generation of power and heat from biomass waste in palm oil_industry.

Increasing the number of the food solid waste in the Malaysia give a negative impact to environment. Food waste is a major environmental problem that contributes to landfill congestion and greenhouse gas emissions. redirecting food waste to anaerobic digestion plants for biogas generation extracts useful energy while reducing the volume of garbage transported to landfills. This reduces the environmental effect of food waste and promotes a circular economy approach the negative effects of such practices include air and water pollution, land degradation, methane and harmful leachate emissions, and climate change. These effects impose enormous environmental and public health costs on inhabitants, with disadvantaged socioeconomic groups carrying most of the burden. In biogas production by using the food solid waste in Malaysia as they main raw material, it can help in reduce the waste, gas emission and the greenhouse effect to the earth.

Advantage of the research biogas generation from MSW is can help in manage waste in Malaysia. This method decreases the amount of waste that ends up in landfills and produces a renewable energy source by using the anaerobic digestion of organic waste to create biogas. Utilizing biogas technology can have a major impact on energy production, waste reduction, and ultimately environmental sustainability. The fundamentals of biogas technology, its potential to reduce waste, and the opportunities and challenges associated with its application will all be covered in this thesis. It seeks to illustrate how biogas technology shapes a sustainable future through this investigation (Yong, Bashir, & Hassan, 2021).

The generation of biogas offers a substantial chance for economic growth. Biogas is a renewable energy source that may be used to heat buildings, generate electricity, and power cars. This can save money and possibly generate income from the sale of extra energy. Additionally, the business generates jobs in associated industries including construction, transportation, and equipment manufacturing in addition to directly supporting the upkeep and operation of biogas facilities. food can reduce their landfill expenses and increase the longevity of their current sites by redirecting organic waste from landfills to biogas facilities. The procedure also lessens the requirement for chemical fertilizers, which results in additional cost savings (Yong, Bashir, & Hassan, 2021).

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Anaerobic Digestion (AD)

Anaerobic digestion is a process in which microbes break down organic materials in the absence of oxygen, such as animal dung, wastewater biosolids, and food waste. Anaerobic digestion for biogas generation proceeds in a sealed tank known as a reactor, which is designed and built in a variety of forms and sizes based on the location and feedstock circumstances. These reactors contain complex microbial communities that break down (or digest) the waste to produce biogas and digestate (the solid and liquid end-products of the AD process), which are released from the digester (*How Does Anaerobic Digestion Work? | US EPA*, 2019).

In the absence of oxygen and in the presence of anaerobic microbes, anaerobic degradation of organic material occurs. AD can be triggered by a series of metabolic interactions between different kinds of bacteria. Hydrolysis/liquefaction, acidogenesis, and methanogenesis are the three stages. The first kind of bacterium secretes enzymes that hydrolyze polymeric materials to monomers like glucose and amino acids. These are then transformed to more volatile fatty acids, H_2, and acetic acid by the second group of bacteria, acetogenic bacteria. Finally, the methanogenic bacteria convert H_2, CO_2, and acetate into CH_4. The AD is performed in massive digesters that are kept at temperatures. The different type such as psychrophilic range in 0°C-20°C, mesophilic (20°C-45°C), and thermophilic (50°C-70°C) has a different type of temperature with microbe activity in the feedstock using (*Sci-Hub | Biogas. Advanced Renewable Energy Systems, 426–472 | 10.1016/B978-1-78242-269-3.50017-6*, 2014). The gas produced by this anaerobic fermentation process has the ability of burning, it consists of at least 45% methane gas. It has a calorific value of 8,900 kcal/m3 for pure gas (100%)

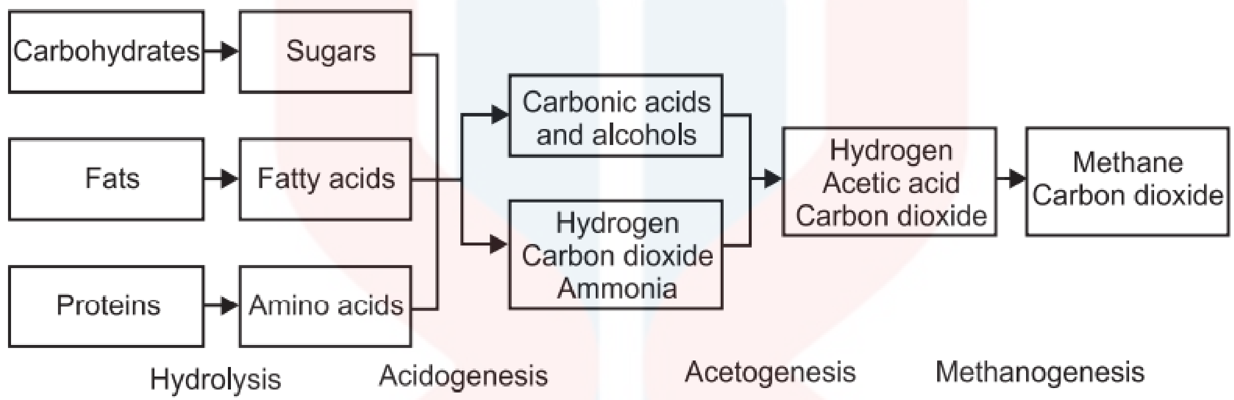


Figure 2.1: The Key Process Stages of Anaerobic Digestion

1. **Input Materials**: The process begins with carbohydrates, fats, and proteins, which are types of organic materials.
2. **Hydrolysis**: These materials undergo hydrolysis, a process that breaks them down into simpler compounds: carbohydrates into sugars, fats into fatty acids, and proteins into amino acids.
3. **Acidogenesis**: The sugars, fatty acids, and amino acids are further broken down into carbonic acids and alcohols during acidogenesis.
4. **Acetogenesis**: During acetogenesis, the carbonic acids and alcohols are converted into hydrogen, acetic acid, carbon dioxide, and ammonia.
5. **Methanogenesis**: In the final stage, methanogenesis, methane and carbon dioxide are produced from hydrogen and acetic acid.

Methanogens are strictly anaerobic microorganisms which produce methane gas as their end product of metabolism. They can only use a limited number of simple carbon compounds as substrates; the most common substrates are H_2–CO_2 and acetate. Methanogens that utilize methanol, methylamines, and dimethyl sulfide are known as methylotrophs (Zinder, 1993). Methanogens alone are not able to convert complex organic substrates (like food waste) to methane; moreover, fermentative and acetogenic microorganisms are needed. Complex substrates are first hydrolyzed by fermentative bacteria, followed by fermentation, which results in the production of acetate, longer-chain fatty acids, carbon dioxide, H_2, NH_4 +, and HS. Acetogenic bacteria that use H_2 eat carbon dioxide and H_2 to make additional acetate.

2.2 Biogas

Biogas is a gas that is generally formed by the biological decomposition of organic materials in the absence of oxygen, that a form of biofuel that is produced from natural material. This biogas is mostly composed of methane and carbon dioxide. Another form of gas produced by the utilization of biomass is wood gas, which is produced by gasifying wood or other biomass. This gas is largely composed of nitrogen, hydrogen, and carbon monoxide, with trace quantities of methane (Sci-Hub | Biogas. Advanced Renewable Energy Systems, 426–472 | 10.1016/B978-1-78242-269-3.50017-6, 2014). Methane, hydrogen, and carbon monoxide may all be burned or oxidized with oxygen. The oxygen content of air is 21%. Because of this energy release, biogas may be utilized as a fuel. In any country, biogas may be used as a low-cost fuel for any heat purpose, such as cooking. It may also be use in contemporary waste management facilities to power any form of heat engine, generating either mechanical or electrical energy. Biogas production can be low cost because raw material use in this process easy to get that from organic waste feedstock for the generation of biogas, discovered in a recent study that food waste had the highest methane outputs with biogas yields. The proved the possibility of using home food waste, demonstrating that a 72kW biogas plant could be built to generate around 630,00 kWh of power for 500 households (Hanif et al., 2020).

Biogas generated by anaerobic digestion of feedstocks consist mainly of methane (CH_4) typically produce around 40%-65% and carbon dioxide (CO_2) will be produce around 35%-55% , with minor quantities of hydrogen sulphide (H_2S) (0.13% v/v), moisture, and other small amounts of impurities. The anaerobic digestion (AD) process is divided into four stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis, with each stage heavily controlled by microbial populations. These microbial populations are extremely sensitive to temperature and pH (Sci-Hub | Biogas Production from Waste: Technical Overview, Progress, and Challenges. Bioreactors, 89–104 | 10.1016/B978-0-12-821264-6.00007-3, 2020).

2.3 Characterization Parameter

In characterize of the parameters are being used to assess the potential for methane production from food solid waste in Malaysia. The parameter choose is to know the potential of the biogas produce methane in the optimize condition is in pH, time, and the temperature use in this experiment will affect the concentration of those parameter use.

2.3.1 Ph Value

The yield of biogas appears to be controlled by factors such as solid content, pH, temperature, mixing/agitation, retention period, and so on. The effect of pH on biogas production is experimentally investigated in five laboratory-scale batch reactors-maintained pH range at 5, 6, 7, 8, and 9. The reactors were run at a mesophilic temperature (Ali et al., 2019). In this study experiment use 3 phase of the range pH which is in acid in range 6-8 for the investigate the reaction of the biogas production. For this experiment we will measure before and after the digestion process.

2.3.2 Temperature

Temperature is a classic example of how these bacteria may be extremely sensitive to changes in their environment. The two kinds of bacteria (acidogens and methanogens) that are involved in anaerobic digestion function at three different temperatures: psychrophilic (25°C), mesophilic (25-40°C), and thermophilic (45-60°C). (Onwuka, 2023). Although anaerobic digestion may occur at normal temperature, any way of keeping digester temperature near optimal will increase digester performance in food waste. In this experiment that has decide three different temperature range choose for the experiment, the temperature use like 20°C, 30°C and 40°C, the selection of the temperature base on the type of the microbe work in optimum condition.

2.3.3 Time

The time it takes to generate biogas from food waste in a lab-scale anaerobic digestion system depends on a number of parameters, including temperature, substrate composition, inoculum supply, and process conditions. In a lab-scale setting, the digesting process might take several days to several weeks or event month to achieve the optimum operation condition. It takes time for an anaerobic digestion system to grow a stable microbial community and reach optimal operating conditions.

2.4 Food Waste

Food waste can be category in municipal solid waste (MSW) that can be found in household, restaurant and stall with serve base on food product. By increasing the number of the waste by years can give the negative impact to the environment in health in this country, it because the gas produces by the waste such as Carbone dioxide, methane gas and other additional gas that produce form the landfill or dumping area. The increase of waste make it allowed the increasing vector like flies, mouse, mosquito, and cockroach that help spread dangerous illness to the resident nearby area.

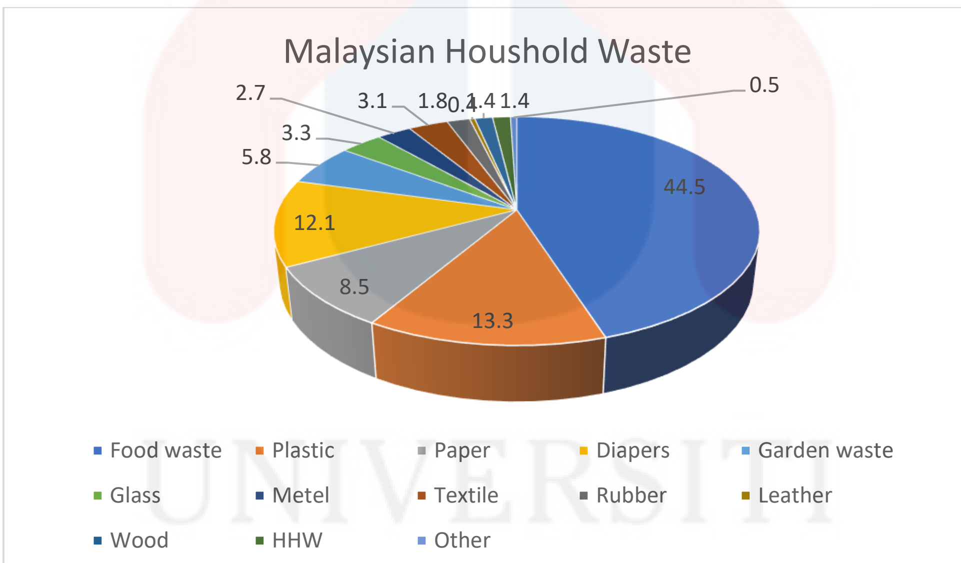


Figure 2.4. Malaysian Household waste (Kesejahteraan Bandar et al., n.d.)

In contact of renewable energy sources of biogas, food waste be a good option to produce gas methane as a renewable energy to be use in daily life or as commercial. Base on the chart we can define the baggers percentage of the daily waste from household is food waste with 44.5%, with the larges amount of the waste it be a perfect as a renewable energy to produce methane gas for the biogas with anaerobic digestion. The anaerobic digestion is a treatment to convert the feedstock which is from food waste to producing the gas that can be use in daily life as heating system, the digestion includes the microorganisms to help in composition feedstock without using the air in this process (*How Does Anaerobic Digestion Work? | US EPA*, 2019).

food solid waste increase by year give a negative impact to the environment, because solid waste decomposes anaerobically in landfills and our solid waste burning facilities release nitrous oxide into the atmosphere, solid waste directly contributes to greenhouse gas emissions. With the gases release from the waste potential of the global warming be high because of the methane has 21-time warming potential of Carbone Dioxide and Nitrous Oxide has 310-time warming potential ("Climate Change and Waste," 2020). The increasing of the global warming can give the negative impact to the human and the environment such as melting of ice in north pole make the level of see increase, the effect to the human is will frequently flood in their area and the daily will be warmer.

2.5 Response Surface Methodology (RSM)

Response Surface Methodology (RSM) is first presented by Box and Wilson, is a set of statistical and mathematical methods designed to analyze situations like the one being asked using an empirical model. In further detail, its goals are as follows to produce knowledge within the targeted experimental domain. to calculate the experimental variability of pure error with accuracy. To ensure that the suggested model and the experimental data are sufficiently similar that make the lack of fit easier to notice, next is to accurately and precisely forecast the observed response in areas of the experimental domain where no trials were conducted and it help to make the decision making possible under uncertainty conditions, reducing the ambiguity in this experiment ("Sci-Hub | Response Surface Methodology. Comprehensive Chemometrics, 345–390 | 10.1016/B978-044452701-1.00083-1," 2023).

The researchers use the journal from the internet with the same title and the parameter use in this experiment, the parameter need be including Ph, temperature and time to produce biogas in this experiment. The data from RSM will be use to this experiment to take the optimization production to produce methane gas detector and researchers will be run actual experiment in lab scale to compare data get.

CHAPTER 3

MATERIALS AND METHOD

3.1 Material

3.1.1 Apparatus and Equipment

Biogas Measurement Technique

Utilized water displacement, plunger displacement, commercial gas chromatography, respirometer, and manometric methods for accurate biogas measurement. Employed a purpose-built respirometer for real-time gas output measurements. A manometric are process dealing with small quantities of gas generation, Utilized manometric cap according to Rostami (2020) for small gas generation processes (Rostami, 2020). Measure the food waste in beaker about 700ml for each beaker. By using the blender to shredded and crunch the waste to a tiny particle for the digester process. Add 2-cylinder 1L with half of water to each other for gas storage, fill full of water in basin to put the inverted cylinder to get the volume of gases in the end. To stand and stabilize the inverted cylinder in gas storing use a retort stands to secure the cylinder. Tube system be used to make a transport of gas from the anaerobic digester to the storing measurement cylinder.

Food Waste Preparation

The collection of the food waste will be shredded I a beaker around 700ml for each using a blander to enhance the digestibility in process. The set up 2-cylinder 1L configuration with water for gas storage and by using basin to submerge an inverted cylinder for precise gas volume measurement.

Tube System for Gas Transportation

To establish a tube system to transport gas from the anaerobic digester to the measuring cylinder.

Water Bath

Water bath use to employed a water bath to control digester temperature (30 to 40°C) at the study's outset.

Microscopic Analysis

Microscopic use to utilized light microscopy for identifying microorganisms in food waste. The microorganism was be identity by the cell morphology, arrangement and the size of microbe. Light microscopy is a crucial technique for visualizing microorganisms using visible light, it enables the examination of cellular architecture, morphological features, and cellular configurations. Employed various techniques such as brightfield, darkfield, phase contrast, and DIC microscopy for microbe visualization. Light microscopy is a common method for observed cell morphology, arrangement, and size to identify microorganism. It allows for the examination of microorganisms' cellular structures, morphological characteristics, and cellular configuration. In this experiment will be use shredded food waste to us in light microscopy.

Methane Gas Detector

A methane gas detector is a device that utilized a methane gas detector to measure concentration, ensuring safety in combustible environments. Because methane is a combustible and potentially toxic gas, detecting its presence is critical for safety, particularly in sectors like oil and gas, mining, wastewater treatment, and agriculture. In this experiment methane gas detector will be used to detect the concentration of methane gas, checked sensor inlet exposure to air and monitored results on the screen.

3.2 Method

3.2.1 Sample Selection

The sample of the food waste use in this study will be Collected food waste samples from the University Malaysian Kelantan Campus Jeli's nearby restaurant and household, the type of food waste will be collected randomly to use in digester, the food will be randomly selected food waste types (meat, vegetables, etc.) based on garbage content. Sample collection occurred 2 days before the experiment, with a target of 1 kilogram in each set experiment.

3.2.2 Storage

Food waste would be store in a controlled environment to minimize the odor and prevent from the pest infestation. The collection for the food waste need to sealed the containers to limit oxygen intake and kept samples in a chiller at low temperatures to stop the reaction organisms in feedstock, it can be put in chiller.

3.3 Process and Experiment Setup

In the feedstock preparation by using the mix food waste that was collect from the household and restaurant waste. From the mix food waste collected need to be shredded into tiny particle around 70-80% of a 1-liter beaker. In this experiment using 80% of the 1liter beaker use which is 800g of mix food waste for optimal digestion.

For the setup in water displacement technique, it will be use 1L of cornicle flask for the digester in feed stock. Then connect two 250ml of measuring cylinder for gas storage, each flask needs to be connected by pipe for the gas flow from the digester to the storing flask, by using two insulating cylinders is caused as a storage figure for the gas resulting from this experiment. Ensure an airtight lid to create an anaerobic environment in the digester by sealing digestion with lid and parafilm, this airtight lid can prevent the oxygen in or out in the digester and to prevent from gas leaked. In digester process need to maintain a constant temperature in (45°C) of the digester with the specific range of temperature using water bath technique. The water bath technique to make sure the microorganism breaks down the organic matter in the digester can grow in optimum condition to produce biogas as bioproduct. Water bath is a container or sample is placed into a bigger container filled with water that has been heated or cooled to a specified temperature, the water bath creates a temperature environment that is stable and consistent around the sample.

pH monitoring to measure pH before and after the digestion process, maintaining a range of 7.2. this experiment pH will be use range 7.2 and it will be measure before and after the digestion process. Recoded data over 1 week, 2 weeks, and 4 weeks.

Using the gas volume cylinder in the water displacement technique, gas from the digester has determine mole of gas volume, the gas can be calculating base on the level of water in cylinder. The data will be collected weekly using the gas volume cylinder. At the same time methane gas detector will be use to utilize the quality of methane gas. In the same time the data from the experiment need to be collect and the result need to be record.

Microorganisms identification in the food waste feedstock use a nutrient agar plate and streaking technique to grow the microorganism. The agar plate preparation by mix the agar nutrient with the distill water and sterilizing by using autoclave at 121°C for the 15 minutes and incubated plate before use and identified microorganism. The sample of microorganisms will be use food waste before the anaerobic process start and by using streaking technique, striking the microbe to the agar plate and seal the sample using parafilm the keep the microbe not interact with environment. The sample can be use in 2 or 3 day in identification process by using light microscopy. To employing a clear vision of microbe researchers use oil lens for clear vision.

3.4 Research Flow Chart

The research flow chart will be show the procedure of biogas production in lab scale by using anaerobic digestion and using water bath as temperature control.

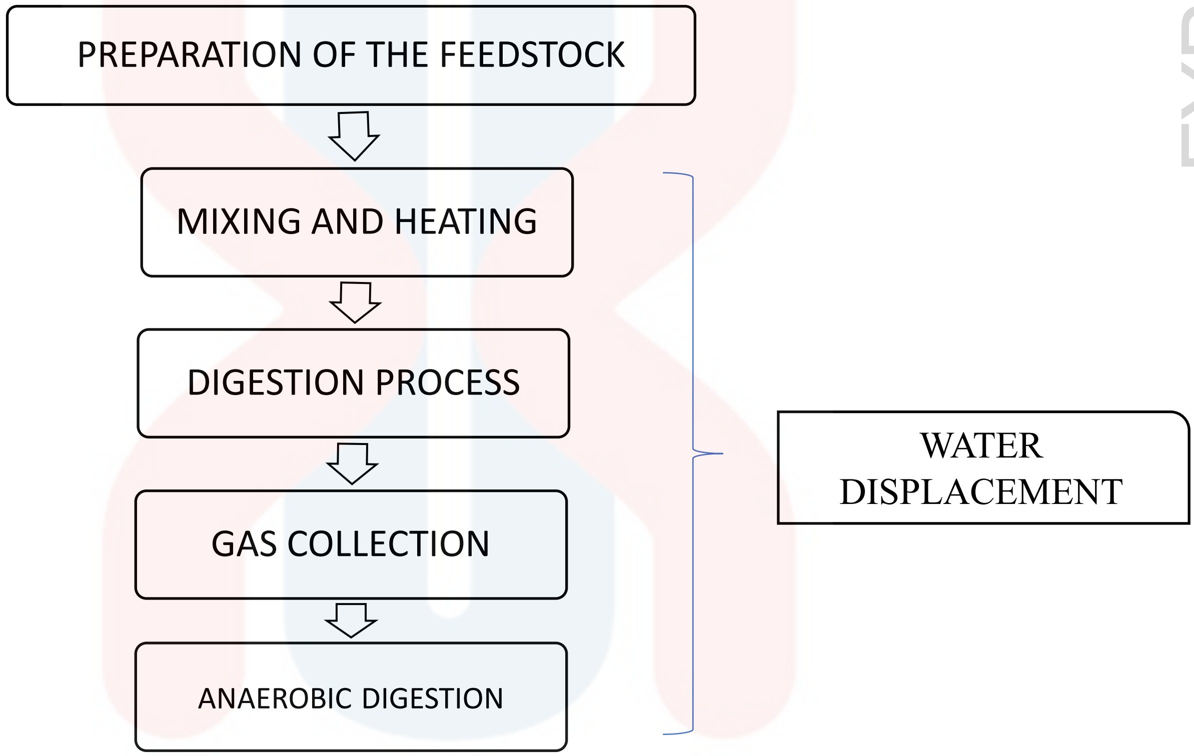


Figure 3.1: The research flow chart of the biogas production from food waste

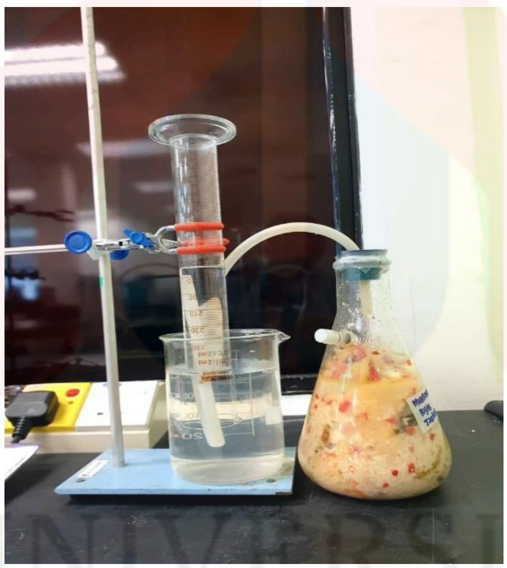
CHAPTER 4

RESULT AND DISCUSSION

4.1 Result

4.1.1 Gas Production Results

The set up in small scale laboratory equipment in produce biogas production by using food waste. The result can be got by measuring cylinder in the end of result.



Run	Number				
	pH	Temperature (^0C)	Time (week)	Gas yield (ml)	Methane gas
Test 1	7.2	45	1 week	50	0
Test 2	7.2	45	2 weeks	75	0
Test 3	7.2	45	4 weeks	250	0

Table 4.1.1: Gas Production

4.1.2 Microorganisms Identification

The food waste sample was inoculated on an agar nutrient plate and left for three to four days before the identification process using a 100x oil lens microscope.

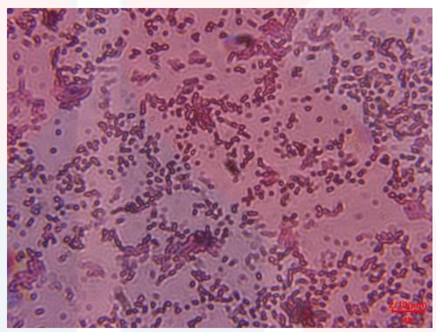
Categories	Food waste
Sample picture	
Technique	Streak plate
colony	White cream in color
Shape	Rod-shape
Motility	motile
organisms	Acetobecterium bacteria

Table 4.2: Microbial Identification from food Waste on agar nutrient plate

4.2 Discussion

4.2.1 RSM Characterization

In the Response Surface Methodology (RSM) characterization, approximately 30 sample runs were conducted to optimize biogas production. The experiment focused on temperature, pH, and agitation time, with significant impacts observed. The results indicated that biogas production increased up to 45°C, beyond which it declined. The ideal pH was found to be 7.2. The experiment achieved a 748% increase in biogas yield at 45°C and pH 7.2, compared to the baseline yield of 250ml without methane gas.

The acidic pH (below 6.5) in biogas production will slowdown the methanogenesis process which mean the bacteria activity and the result will be accumulative of volatile fatty acid, hindering the efficiency of anaerobic process. The decrease of pH negatively affects the balance of microbial community, leading to the less favorable environment for the methane production. When the production become alkaline pH (above 8.5), it has detrimental effect on the anaerobic digestion process, the activity acid-forming bacteria id hindering, disrupting the initial stage of the organic matter breakdown. The environment become less conducive for the methanogenesis bacteria, its accumulation of the ammonia, a byproduct that can be toxic to the microbial community.

Base on the result we found that the yield of biogas stopped with a further increase in temperature and that the dependency for the production of biogas grew with temperature increases up to 45°C. The production up to 50°C output of biogas appears to be exactly proportional to temperature increase, beyond that point. The yield of biogas was observed to decrease as temperature increased, it was discovered that the production fell down around pH 7.2, which was the ideal value. The microorganisms involved in the creation of biogas are extremely sensitive, and their development and production are dependent on a particular pH and temperature range. In light of the findings, a prior investigation revealed that a pH of 6.3 to 7.8 is ideal (Gopal et al.).

Comparison data from the RSM in optimization of the biogas production is has produce 748% of biogas yield with use 45°C in temperature and pH in range 7.2 (Gopal et al.). In the experiment doing of the researcher came with data 250ml of gases yield in the result of experiment without methane gas in.

4.2.2 Microbial Identification

Microorganisms were identified from food waste using agar plate culture, specifically targeting Acetobacterium. The isolated colonies exhibited a spherical shape and motility, observable under a 10x oil lens microscope. Acetobacterium, crucial in anaerobic digestion for organic substrate breakdown and biogas production, was identified. Isolating and characterizing strains like Acetobacterium can enhance biogas yields, contributing to waste management and sustainable energy goals.

Identified the characterization of the microbe these strains can be show in spherical shape and motility characteristic of the Acetobacterium and it can be seen via light microscopic in 10x zoom oil lens. The colony of the bacterial can be found by streaking method in agar plate from the sample of food waste.

During anaerobic digestion, acetobacterium is essential to the breakdown of organic substrates and to the resulting production of useful gases like methane. In order to discover highperforming isolates with increased metabolic activity for acetate synthesis, this study will isolate and characterize strains of Acetobacterium using agar plate cultures. It is highly promising to optimize microbial consortia by the integration of such resilient strains into biogas production systems, which would ultimately result in higher biogas yields. Along with advancing our basic knowledge of the ecology and physiology of Acetobacterium, this research offers useful insights for optimizing biogas production techniques, which is in line with the larger objectives of waste management and sustainable energy generation.

4.2.3 Methane Gas Analysis

Methane gas analysis employed a detector with low and high sensitivity. In the experiments with food waste, methane gas was consistently absent (0%) at both sensitivity levels. However, gas production increased over time. The study identified various gases produced, including carbon dioxide and nitrous oxide, emphasizing the potential environmental implications. A comparison with 2011 U.S. methane emissions highlighted the relatively low methane contribution from MSW landfills.

Base on the gases get in this experiment that we can identify a few type results of gases that produce in this experiment, the gas that produce from the food waste in the experiment which is process also generates carbon dioxide (CO_2), a further significant greenhouse gas. This happens when microorganisms use aerobic respiration, where they take in oxygen and organic matter and produce carbon dioxide as a byproduct. Nitrous oxide is one of the other gases created, especially when digested food waste is composted. Ammonia and sulfides are among the two to ten percent of landfill gas that isn't made up of carbon dioxide. The precise makeup of these gases can change based on the particular circumstances and waste types involved ("Basic Information about Landfill Gas | US EPA," 2016).

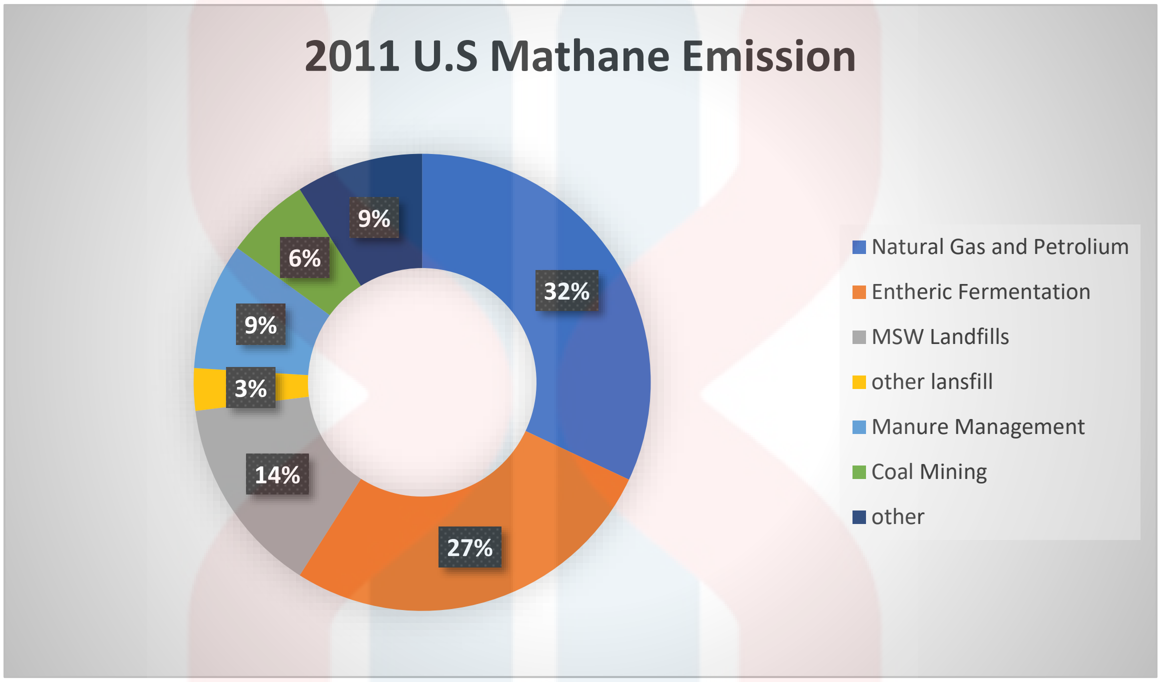


Figure 4.2: Methane Emission, 2011 U.S

Base on the ("Basic Information about Landfill Gas | US EPA," 2016) methane emission I US 2011, table 4.2 shows the different sources of methane emissions. The largest segment is in Natural Gas and Petroleum Systems at 32%, followed by Enteric Fermentation at 27%, and MSW Landfills at 14%. Manure Management and Other each contribute 9%, Coal Mining is at 6%, and the smallest segment is Other Landfills at 3%. This chart provides a clear breakdown of the various sources contributing to methane emissions in the U.S. By using the feedstock MSW landfill in produce the biogas it can be define only 14% of the methane will produce from the feedstock that define a low chance.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

The experiment underscores the pivotal role of parameters such as time, pH, and temperature in optimizing the biogas production process through anaerobic digestion. Proper management of these parameters can create favorable conditions for microorganisms, enhancing the production of gases like carbon dioxide.

The concept of the anaerobic digestion for the food waste is a fermentation process without air, proves effective in converting food waste into biogas and methane. This renewable energy source reduces reliance on nonrenewable resources like petroleum in daily life.

The objective in this experiment in this project is to identify the microbe crucial for biogas production, with Acetobacterium bacteria identified as a key player, their prevalence in food solid waste (MSW) contributes significantly to the digestion process. The bacterial was be identify be the shape, colony on the bacteria, by suing 10x oil lens. The type of the bacteria is a majority in the MSW to help in the digestion process.

5.2 Recommendation

After the investigation in this current research it might be view has produced a gas in the end of experiment, While the current research successfully generated gas, the absence of detected non-methane gases suggests a need for enhancers in the lab-scale setup.

- Consider incorporating additional substrates, such as cow dung and other byproducts of MSW, into the digester process for improved gas production.
- Enhance substrate homogeneity and microbial interaction by installing a stirring or mixing system in the digester.
- Introduce enzymes to expedite the breakdown of complex organic molecules, facilitating a faster gas production process in the digester.

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