PRODUCTION OF BIOGAS BY USING AIR STRIPPING AS PRE-TREATMENT PROCESS IN ANAEROBIC DIGESTION OF PALM OIL MILL EFFLUENT (POME)

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ABSTRAK

Kajian ini bertujuan untuk menghasilkan biogas daripada effluen minyak kelapa sawit dalam anaerobik melalui proses pra-rawatan pelucutan udara. Pelucutan udara adalah proses melalukan udara melalui air yang tercemar dengan bahan cemar yang meruap dalam system di atas tanah. Pergerakan udara daripada proses ini menyebabkan bahan meruap pada kadar yang cepat. Pelucutan ammonia nitrogen pula adalah teknik yang menggunakan kos yang rendah dan tenaga input yang sedikit yang melibatkan pemindahan ammonia bebas daripada sisa air kepada fasa gas. Kadar pengurangan ammonia nitrogen yang tinggi membantu dalam meningkatkan penghasilan biogas melalui proses anaerobik. Anaerobik pula merupakan proses di mana bakteria memecahkan bahan organic tanpa kehadiran oksigen untuk menghasilkan biogas. Ia adalah kaedah yang mesra alam untuk merawat dan memulihkan biotenaga daripada pelbagai sisa organic. Dalam kajian ini, effluen minyak kelapa sawit mentah akan diuji kandungan ammonia nitrogennya dan kepekatan pH akan diubah daripada berasid 4.17 kepada alkali 8. Kemudian, 550 ml POME diisi dalam dua botol kaca untuk menjalani proses pelucutan udara. Salah satu botol akan menjalani proses pra-rawatan pelucutan udara manakala satu lagi botol kaca yang tidak diubah kandungan pHnya akan digunakan sebagai botol kawalan yang akan menjalani proses anaerobik tanpa pra-rawatan. Pra-rawatan pelucutan udara ini akan menggunakan kadar aliran udara sebanyak 4 L/min selama 1, 2, 3 dan 4 hari. POME yang telah dirawat akan diuji kandungan ammonia nitrogennya dan keputusan ujian parameter sebelum dan selepas proses pra-rawatan pelucutuan udara akan dibandingkan. Selepas itu, POME yang telah dirawat akan dibiarkan selama 7 hari untuk proses anaerobik bagi mendapatkan biogas. Jumlah pengeluaran biogas yang terperangkap dalam beg nalophan akan dikira melalui kaedah anjakan air. Daripada semua data yang diperolehi, ammonia nitrogen telah berkurang sebanyak 92.8% daripada 0.42 ml kepada 0.03 ml. pengeluaran biogas juga menghasilkan sebanyak 5.54 ml/h unutk kadar biogas basah manakala 5.23 ml/h untuk kadar biogas kering. Namun begitu, walaupun masa pelucutan hari 4 kuarang menghasilkan biogas, kualitinya lebih tinggi berbanding masa pelucutan hari 1. Hasil rumusan kajian ini adalah semakin tinggi kandungan pH beserta masa pelucutan yang lebih lama, semakin tinggi pengurangan ammonia nitrogen yang meningkatkan kadar pengeluaran biogas.

ABSTRACT

This study aims to produce biogas from palm oil mill effluent in anaerobic digestion through the pre-treatment of the air stripping process. Air stripping is the process of moving air through contaminated water with volatile contaminants in a treatment system above ground. The air movement process causes volatiles to evaporate at a faster rate. Ammonia stripping is a cost-effective technique that requires little energy inputs and involves the transfer of free ammonia from wastewater to the gas phase. High removal of ammonia nitrogen helps in enhancing biogas production through anaerobic digestion while anaerobic digestion is a process which bacteria break down organic matter in the absence of oxygen to produce biogas. It is an environmentally friendly method for treating and recovering bioenergy from a variety of organic wastes. In this study, raw POME will be tested for its, ammonia nitrogen content and changing the pH content of raw POME from acidic 4.17 to alkaline 8. Then, two bottles of 550ml POME are filled in the glass bottle to undergo the air stripping pre-treatment process. One of the bottles will undergo an air stripping pre-treatment process while another glass bottle will be used as a control for an anaerobic digestion process without pre-treatment. Air stripping pre-treatment will be conducted using an airflow rate of 4L/min for 1 to 4 days. The treated POME will be tested for its ammonia nitrogen content and the results of the parameter test before and after the air stripping pre-treatment process will be compared. After the pre-treatment process, POME will undergo anaerobic digestion for biogas production. A glass bottle containing treated POME will be connected with a nalophan bag. The process of anaerobic digestion will be taking place for 7 days. The amount of biogas production trapped in the nalophan bag from the anaerobic digestion process will be measured using the water displacement method. From the results, the reduction of ammonia nitrogen of POME is reduced to 92.8% from 0.42 ml to 0.03 ml. The production of biogas resulted in 5.54 ml/h for the rate of wet biogas production while 5.23 ml/h was collected for the rate of dry biogas production. Even though stripping time 4 produces less biogas, the quality is higher compared to stripping time 1. This study also concludes that the higher the pH content along with longer stripping time, the ammonia nitrogen reduction will be high thus enhancing the production of biogas.

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LIST OF SYMBOLS

°C	Temperature
CO_2	Carbon Dioxide
H2	Hydrogen
CH_4	Methane
CH_3-N	Ammonia Nitrogen

LIST OF ABBREVIATIONS

POME	Palm Oil Mill Effluent
HRT	Hydraulic Retention Time
AD	Anaerobic Digestion
AS	Air Stripping
COD	Chemical Oxygen Demand
BOD	Biochemical Oxygen Demand
TSS	Total Suspended Solid
TS	Total Solid
SS	Suspended Solid
O&G	Oil and Grease
TDS	Total Dissolved Solid
GHG	Green House Gases
GWP	Global Warming Potential
USEPA	United States Environmental Protection Agency
LFG	Landfill Gas
ASBR	Anaerobic Sequencing Bench Reactor
CSTR	Continuous Stirred Tank Reactor
UASB	Up-flow Anaerobic Sludge Blanket
OLR	Organic Loading Rate
R&D	Research and Development
CHP	Combined Heat and Power

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INTRODUCTION

1.1 Introduction

Malaysia's current modernization and population have demanded more resources on energy especially on fossil fuels that are not sustainable and provide serious damage to the environment and human health (Olabi, A., & Abdelkareem, M. A., 2022). The only key to this problem is developing and improving renewable energy to help avert the risk of climate change, or human health and the approach must be sustainable (Amjith & Bavanish, 2022). Renewable energy sources included biomass, solar, mini-hydro power, industrial wastes, and biogas. Among these sources, biogas is a prominent green energy source because of its potential to handle organic waste while still producing electricity, solving all issues at the same time (Chien Bong., et al. 2017).

Malaysia has tropical forests and a humid climate all over the year. It is an excellent opportunity to make full use of agriculture and tropical rain to generate biomass (Al Mamun & Torii, 2017). Due to that, Malaysia's government has been enacting several policies that could aid in the development of renewable energy technologies and improve its contribution to the national energy mix, thus reducing the country's reliance on fossil fuels (Hashim, H et al., 2017). There are more than 103 million tons of biomass that Malaysia produces, collecting from agricultural wastes that represent 91% of the biomass amount from palm oil mill residues, forest residues, and municipal wastes (Salleh et al., 2020).

Malaysia is the second-largest country after Indonesia that produces and exports palm oil all over the world. Oil palm plants are spread among all states in Malaysia and 76 of them are large factories with processing capabilities are over 250,000 tons of fresh fruit bunches (FFB) per year (Chala et al., 2019). Each year, nearly 80 million tons of FFB are processed in 406 palm oil plants, and approximately 54 million tons of palm oil mill effluent (POME) are produced. POME contains 95% of water and the rest 5% solid. However, untreated POME released methane that is 25 times more dangerous than carbon dioxide (CO2) (Akhbari, A., et al. 2021).

Relying on the operation of the procedure, POME in its untreated shape is a high-quality waste. It is mainly generated from oil extraction, washing, and cleaning process in the mill that contains suspended solids (SS), total dissolved solids (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), fat oil, and grease. Anaerobic Digestion (AD) is one of the cost-effective and environmentally friendly methods that can treat and recover bio-energy from all kinds of types of organic wastes (Choong et al., 2018). On the other hand, treated POME produced biogas through anaerobic digestion that contained 40% to 70% biogas. Pre-treatment of air stripping can be used to treat POME for the anaerobic digestion process for biogas production (Sarwani et al., 2019).

The air stripping pre-treatment method is known to reduce ammonia that can increase biogas production in anaerobic digestion. The efficiency of air stripping pre-treatments on both ammonia removal and to increase biogas production will assess in batch tests. It requires low energy input in which the ammonia is transferred into the gas phase. Further treatment of biogas into bio-methane can be used as fuel for transportation that has similar engine performance and exhaust emission and becoming one of most sustainable, economical, and environmentally friendly vehicle fuels later on (Folino et al., 2020). Thus, this study intended to evaluate the air stripping as a pre-treatment to produce biogas in anaerobic digestion of palm oil mill effluent.

1.2 Problem Statement

Every year, the number of palm oil plants is increasing, leading to an increase in fresh fruit bunch waste or effluent discharge. Malaysia contributes approximately 30% of global output and 37% of global exports, which contribute to the growth of domestic products (GDP) (Kushairi, 2017). From the perspective of every palm oil factory, Palm Oil Mill Effluent (POME), is known to be a major problem due to its voluminous abundance and disposal problems. Direct discharge of POME on land resulting in waterlogging of the soil, kills the vegetation on contact and clogging. If discharging the effluent to waterways can cause water depletion that results in aquatic pollution (A Aziz et al., 2020).

Untreated POME released methane gas that has 25 times the possibilities for greenhouse gas emissions (GHG), which has higher global warming potential (Sarwani et al., 2019). According to Shahidul et al (2018), methane is a heat and energy source that currently appearing as a Global Warming Potential (GWP) and contributing to climate change. Untreated POME also has highly polluted aquatic life by depleting dissolved oxygen. Due to this, the air stripping pre-treatment process will help in reducing ammonia nitrogen since ammonia nitrogen can also contributes to GHG. The great removal of ammonia nitrogen inside the POME produces safer and cleaner methane gas inside the biogas production thus protecting the environment.

For significant methane yields, the substrates for AD, which are typically activated sludge, energy crops, agro-industry residues, and animal breeding farms, should have a balanced C/N (carbon/nitrogen) ratio, a Ph between 6.5 and 8.0, and a noticeable content of organic compounds (Folino et al., 2020). The high ammonia concentration in the wastewater, on the other hand, will inhibit the activity of methanogenic bacteria in anaerobic digestion plants, resulting in a significant reduction in methane yield. The removal of nitrogen compounds before anaerobic digestion may increase methane production by lowering the toxicity of the compounds to the microbial consortium (Folino et al., 2020). Some Physico-chemical treatments, such as air stripping, can remove nitrogen compounds from wastewater, and thus increase the production of methane.

1.3 Objective

The main purpose of this study is to produce biogas in anaerobic digestion of Palm Oil Mill Effluent (POME) by using air stripping as a pre-treatment process. With this, the following sub-objectives are as follows:

(i) To investigate the reduction of ammonia nitrogen in the air stripping pre-treatment process for anaerobic digestion of POME.

(ii) To identify the amount of biogas in anaerobic digestion by providing the best stripping time and Ph of POME in the air stripping pre-treatment process.

1.4 Scope of Study

This study can improve the production of biogas from anaerobic digestion of POME by reducing ammonia nitrogen using the process of air stripping pre-treatment. POME from the Lepar Hilir 3 Palm Oil Mill will be utilized as a sample for the preparation of the air stripping pre-treatment process to enhance biogas production in anaerobic digestion.

The project started with the collection of POME from the first pit. Then, the raw POME will be tested for its ammonia nitrogen content, and the Ph content will be changed to Ph 8 from acidic content to alkaline for the treated bottle. Two glass bottles will be filled with 550 Ml of raw POME for air stripping pre-treatment and anaerobic digestion process. One of the bottles will undergo an air stripping pre-treatment process while another glass bottle will be used as a control that will undergo an anaerobic digestion process without pre-treatment. The glass bottle will be connected with a nalophan bag and an aerator to supply 4 L/min of airflow rate for the air stripping pre-treatment process. The nalophan bag is used to trap ammonia gas from arises from the pre-treatment process from release to the environment. The air stripping pre-treatment process will be conducted for 1 to 4 days and then the treated POME will be tested for its ammonia nitrogen. The results of the parameter test before and after the air stripping pre-treatment process will be compared.

After the pre-treatment process, POME will undergo an anaerobic digestion process for biogas production. A glass bottle containing treated POME will be connected with a nalophan bag and put inside the water bath at the temperature of 35 °C. The process of anaerobic digestion will be taking place for 7 days. The amount of biogas production trapped in the nalophan bag from the anaerobic digestion process will be measured using the water displacement method. The same processes will be applied to the control jar which contains raw POME that did not undergo the pre-treatment process. Lastly, the production of biogas between control and treated POME will be compared.

1.5 Significance of Study

The finding of this study will give benefits to the new era of renewable energy since the capability of biomass energy to develop more in Malaysia using palm oil mill effluent (POME) and air stripping as the main pre-treatment. At the same time, the sustainability of the environment will be kept as the greenhouse effect can be greatly reduced. This research uses air stripping as a pre-treatment because it is at a low cost but generates a higher amount of biogas production.

Air stripping will reduce the amount of ammonia in the anaerobic digestion system to produce more methane gas. In biogas production, methane gas has the highest composition compared to carbon dioxide. The higher the methane gas collected, the higher the possibility of renewable energy being invented. Too much ammonia will greatly affect the amount of biogas production and it will give the pollutant through the environment. However, there are also have many successful applications of ammonia stripping to various feedstock such as domestic and industrial wastewater.

1.6 Hypothesis

It is hypothesized that based on the study that has been carried out the more ammonia can be reduced along with high Ph content and longer stripping time using the air stripping pre-treatment, the more biogas production can be produced through the anaerobic digestion process.

LITERATURE REVIEW

2.1 Renewable Energy

Renewable energy has the potential to be a turning point for a country's economic development (Mohd Chachuli et al., 2021). There are around 11% of global primary energy came from renewable technologies in the year 2019 (Ritchie, H. 2020). Following the market force concept, Malaysia has been committed to green energy production since 2001 to diversify energy supplies for electricity generation. However, previous attempts had failed, and the government concluded that the business-as-usual solution is unfit and ineffective for long-term growth (Mohd Chachuli et al., 2021).

In 2008, the Malaysian government formulated an ambitious strategy called the National Renewable Energy Policy and Action Plan to ensure a balanced strategy for Malaysia's renewable energy industries, considering the important lessons learned from the previous approach (Mohd Chachuli et al., 2021). The strategy aims to expand the use of renewable energy in the national electricity mix while also promoting long-term socio-economic growth. The strategy further highlights the importance of a comprehensive research and development (R&D) plan as well as human capital development to help the renewable energy sector expand faster, resulting in economic benefits through the production of creative goods and services (Sofian., 2020).

Malaysia declared in 2018 that it had set a goal of using 20 percent clean energy in its generation mix by 2025. At the end of 2018, the Southeast Asian country, which is predominantly powered by thermal power plants, had a 2% renewable energy contribution to its generation mix. Malaysia's renewable energy sector is expected to require RM33 billion (US$8 billion) in investments to reach its 2025 goal (*Global Data Energy*., 2019). The Ministry of Energy, Green Technology, and Water of Malaysia

(MEGTW) is stepping up efforts to promote renewable energy and energy conservation so that the atmosphere and natural resources can be sustained for a long time. The Ministry, in conjunction with the Five Fuel Policy, emphasizes the use of renewable energy in the generation of electricity and biogas production. This proposal was proposed in the Eighth Malaysian Plan (2001 – 2005) and received attention under the Ninth Malaysian Plan (2006 – 2010) (Zakaria., 2019).

Renewable energies will play a major important role in the global energy mix in the long term, thanks to rising energy demand, a firm dedication to mitigating carbon change, technological advancements, and policy support. Countries like Denmark and Belgium, for example, aim to provide 100 percent renewable electricity in their overall energy production by 2050. By 2030, the investments are expected to decrease greenhouse gas emissions by at least 40% while also increasing economic growth and employment production in Europe (Anton & Afloarei Nucu, 2020). A stable and well-developed financial structure encourages more funding for the renewables sector at lower prices, resulting in higher investment and, in exchange, increased energy consumption. Firms will use developed capital markets to reduce their liquidity risk and collect the funds they need to develop energy-efficient technology in the long run. Furthermore, financial growth will aid the redistribution of funds from low-efficiency conventional energy to renewable energy growth (Folino et al., 2020).

2.2 Type of Biofuels

Biofuels are produced from biomass such as microorganisms, or plants to become new type of renewable transportation fuels. Ethanol is the most common biofuel that derive from sugar cane, corn, and sugar beets (Roberts & Patterson, 2018). There are three groups of biofuels.

1. Produced by fermentation into alcohols.
2. Oils separated from biomass and reacted to form hydrocarbons or fatty acid methyl esters.

3. Oils process from hydrogenation to produce hydrocarbons within the carbon range of conventional petroleum fuels.

Biodiesel, the second most prevalent liquid biofuel, is manufactured mostly from oily plants such as soybeans or oil palm and, to a lesser extent, from other oily sources such as waste cooking fat from restaurant deep-frying (Selin., 2019). The details for types of biofuels are shown in Table 2.1.

Table 2.1 Types of Biofuels

Types	Explanation	Sources
Wood	• The most basic form of fuel that derived from organic matter. • Provide biomass burned for fuel in the forms of firewood, sawdust, chips, charcoal, and pellets.	Rankesh, (2019)
Methanol	• Alcohol like ethanol and used as a clean fuel to power vehicle engines especially racing cars. • Similar to methane in chemical composition. • Biomass converted to methanol through gasification and done at extremely high temperatures and in the presence of a catalyst.	
Biogas	• The gaseous form of biofuels. • Mainly composed of methane gas though produces from the process of anaerobic breakdown of biomass. • Being packaged in gas cylinders for household use.	
Biodiesel	• The liquid in nature.	

	• Made through the combination of fats and oils from animals and plants respectively. • Need several chemical processes such as transesterification, which involves esters and alcohols such as methanol and ethanol.	
Ethanol	• Use corn that is rich in sugar to ethanol. • Use corn kernel in the fermentation process for a cheaper cost compare to the entire corn plant.	Peritano, (2021)
Sugarcane	• Brazil is the country that has done the most in using sugarcane for biodiesel. • The price of biodiesel is cheaper than gasoline in Brazil. • Sugarcane is less expensive compared to corn in producing ethanol because it requires fewer chemicals.	
Palm Oil	• Extracted from the fruit of the oil palm tree. • Untreated palm oil effluent can be harmful to the environment so it must be treated first. • Biogas production can be collected using the anaerobic digestion process.	Herkes, (2019)
Oilseed rape	• Known as canola. • China, Canada, and India are individual countries that convert oilseed rape to biodiesel the most. • Oilseed rape can be used in most engines without conversion.	

Biofuels is high-demand energy that contributes to environmentally sustainable since it is a clean fuel source and has a high demand for energy globally. Furthermore, any country can produce biofuels on its own since the energy sources can be found in every state without the need to interfere with other countries' energy sources. Biofuels are also easy to produce and cheaper than fossil fuels and the carbon released by biofuels is naturally occurring and is used by plants for photosynthesis (Rinkesh., 2019).

2.2.1 Biogas

Biogas is produced from a breakdown of organic matter through the absence of oxygen into biogas from the anaerobic digestion process (Adba., 2020). It contains roughly 70% of methane, 30% to 40% of carbon dioxide and the rest is a label with other gases. Some organic matter in to produce biogas is more difficult to break down in digester than others such as livestock waste (Tanigawa., 2017). Biogas can:

- Reduce global climate change emissions by 20%.
- Become a global sustainable industry worth.
- Create millions of jobs in many rural areas.
- Deliver homegrown, distributed, baseload, storable and dispatchable green energy.
- Treat wastes that would otherwise produce harmful methane emissions, recycling them into valuable green energy, biofertilizer, and biochemicals.

Biogas may be used on-site with little to no processing to heat buildings, power boilers, or even the digester itself. Biogas can be utilized in combined heat and power (CHP) operations, or it can simply be converted into electricity using a combustion engine, fuel cell, or gas turbine, and the generated electricity can be consumed on-site or supplied to the electric grid (Tanigawa., 2017). The type of feedstock to enhance biogas production is shown in detail in Table 2.2.

Table 2.2 Types of Feedstocks

Types	Explanation	Sources
Food Waste	• There are 30% of the global food supply lost or wasted each year. • Most of this waste will be sent to landfills where it breaks down to produce methane. • Oil, grease. And fat from the food industry will be collected that can be added to an anaerobic digestion process to increase biogas production.	Tanigawa, (2017)
Landfill gas	• The third-largest source of human-related methane emissions. • Landfills contain the same anaerobic bacteria present in a digester that break down organic matter called landfill gas (LFG). • It can be collected to use as energy instead of allowing it to escape to the atmosphere.	
Wastewater Treatment	• Many wastewater treatment plants already have on-site anaerobic digesters to treat sewage sludge. • However, many from the industry does not have the equipment to use the biogas they produce and flare it instead.	

Livestock Manure	• Lower-energy feedstocks it is pre-digested in the gastrointestinal tracts of the animals. • Livestock manure has a neutral pH and high buffering capacity.	Kirk, (2019)
Aquatic Plant	• Water hyacinth, micro, and macro algae, sea weeds are suitable for bioenergy production. • They do not compete with land resources used for food crop cultivation.	Moutousidi, (2021)
Agricultural	• Agricultural crops and activities that produce residues can be used as feedstock for biogas production. • Cattle dung has been used as one of the solid waste feedstocks in India. • Philippines and Taiwan used pig manure as a feedstock for biogas production. • Poultry wastes are rich in organic nitrogen and relatively lower-carbon sources.	

The anaerobic digesters that fed with just food waste outperformed the co-digesters (food waste and cow dung), most likely owing to the inclusion of more refractory material in the co-digesters in the form of cow manure. Nonetheless, as compared to anaerobic digestion of food waste as the only substrate, co-digestion resulted in greater microbial diversity at both temperatures. This might be due to the increased complexity of feedstocks in co-digestion, which favors a more diverse microbial community (Zamanzadeh., 2017).

2.3 Palm Oil Mill Effluent

Palm Oil Mill Effluent (POME) is an undervalued liquid waste stream from palm oil mills that are extracted during the palm oil extraction/decanting process. It is also viewed as a significant environmental concern, but it is an excellent source of biogas. As a result, several palm oil-producing countries are enacting stricter legislation about the discharge of POME (Langerak., 2020). Palm oil production produces heavily polluting wastewater, which is often discharged in disposal ponds, resulting in the leaching of pollutants into groundwater and soil, as well as the leakage of methane gas into the environment. POME is oily wastewater containing various suspended components that are produced by palm oil processing mills (Zafar., 2020).

Apart from producing palm oil, the oil palm industry also generates a large amount of sustainable and possible oil palm biomass (OPB). The oil contributes just about 10% of the overall dry matter of the palms, with the remaining 90% being oil palm biomass. In 2010, approximately 80 million tonnes of OPB were produced, but this figure is expected to rise to 100 million tonnes by the year 2020 (Zainal., 2018). POME is a non-toxic waste since no chemicals are used in the oil production process, but it has a high oxygen depletion capacity in aquatic systems due to its organic and nutrient content. Oil-bearing cellulosic products from the fruits make up the majority of the suspended solids in the POME. Since no chemicals are used in the extraction of oil, the POME is a rich source of nutrients for microorganisms (Zafar., 2020). As the production of oil palm plantations and palm oil mills continues throughout the year, Malaysia is now one of the world's top producers and exporters of palm oil. Oil palm biomass waste accounted for nearly 47% of the global palm oil supply (Derman et al., 2018).

POME has been shown to contain a high volume of nutrients such as starch, protein, and mineral salts, both of which have been shown to encourage the growth of microorganisms. Microorganisms have been harvested using several techniques. Mechanical, electronic, biological, and chemical processes were used. Microorganisms are extracted using mechanical techniques such as centrifugation, filtration, sedimentation, dissolved air flotation, and ultrafiltration membranes (Louhasakul et al., 2019). The cells with a negative surface charge are concentrated using electrical methods by transferring them in an electric field. Chemical flocculation is caused by inorganic or organic flocculants, as well as certain electrolytes and synthetic polymers. Due to their high efficiencies, centrifugation and filtration have become the most widely used methods for harvesting cells. However, these methods use a lot of energy and require a lot of maintenance (Louhasakul et al., 2019).

The advancement of new biotechnological developments and innovations has turned the role of POME from waste to non-waste or resource. Current trending about POME is biogas capture technology and an integrated POME treatment system with the ultimate goal of zero discharge in the palm oil mill. This can be accomplished by combining multiple bioprocesses to convert POME into value-added materials (Taruna., 2020). POME has a high organic acid content, starch, minerals, and proteins, which makes it a suitable nutrient for biomass development. POME refers to a hazardous waste substance that cannot be released into the atmosphere due to the treatment process. POME can be treated using both aerobic and anaerobic processes. Anaerobic digestion techniques have always been widely used due to their high production rate with low energy consumption and the flexibility in using a wide range of organic wastes including dairy wastewater, sewage sludge, and POME (Akhbari et al., 2019).

2.4 Types of Pre-treatments of POME

Researchers are involved in using palm oil mill effluent (POME) as a feedstock to manage waste produced in the agricultural sector, which comes from the palm oil industry. The use of POME as a biogas source has a positive economic and environmental impact, especially in developing countries (A Aziz et al., 2020). Raw materials that have not been pre-treated take a bit longer to handle than pre-treated raw materials. The type of pre-treatment procedure to use is determined by the type of biogas substrate being used. POME must be carefully prepared before being used for biogas processing since it is a lignocellulosic substance. Pre-treatment is used to make raw materials more palatable to microbial groups, which increases the rate of reaction in anaerobic digestion and, as a result, increases biogas production (Jorat et al., 2020).

2.4.1 Pre-Treatment of POME for Thermophilic Biohydrogen

Several methods for using lignocellulosic biomass for the development of various forms of biofuels have been considered in recent years, including biogas, biodiesel, pyrolytic bio-oil, and bioethanol, whereby biogases may play a significant role in improving energy security. Meanwhile, POME and its derivatives have been identified as high-potential substrates for the production of bio-hydrogen. While POME is relatively resistant to biodegradation, it is regarded as a potential bio-hydrogen substrate due to its high content of carbohydrates, protein, nitrogenous compounds, lipids, and minerals (Mahmod et al., 2017).

Many experiments have been performed on the pre-treatment of POME to improve its solubilization and release the fermentable monomeric sugars that can be converted to hydrogen in the anaerobic fermentation method. Since raw POME is discharged from the mill at high temperatures of about 80–90 °C, it is more likely to be processed in a thermophilic anaerobic environment with fewer difficulties. Furthermore, thermophilic anaerobic POME digestion has been stated to have a higher rate of substrate degradation and biogas generation than mesophilic digestion (Jahim et al., 2017).

In comparison to mesophilic anaerobic digestion, thermophilic anaerobic digestion can be performed at a higher organic loading rate (OLR) with adequate COD removal and biogas generation and little or no microbial washout. Furthermore, mesophilic conditions resulted in a higher concentration of volatile fatty acids (VFAs), which is attributed to lower hydrogen productivity. However, because of the greater process stability, the mesophilic state can still be preferable (Mahmod et al., 2017).

2.4.2 Pre-Treatment of POME for Using Ozonation

Hydrogen output from organic wastes through dark fermentation is seen as a promising solution because it is the cleanest green energy carrier, outperforming methane, gasoline, and coal in terms of energy yields. Biological treatment strategies are the most effective because they are less costly, need less energy, and are incredibly successful. Furthermore, anaerobic digestion is a highly appealing bio-waste management method for reducing emissions and recovering energy (Tanikkul et al., 2019).

Ozone is an effective oxidizing agent that has been investigated for its ability to enhance anaerobic digestibility by breaking down the colloidal structure. The ozonizing method is a fascinating technique for breaking down complex organic compounds into small organic molecules that bacteria can quickly degrade and transform into bioenergy. Ozone pre-treatment methods have been shown to increase biogas production from palm oil decanter cake, molasses wastewater, and solid waste, as well as sludge degradation and dewatering (Booyawanich et al., 2019).

2.4.3 Pre-Treatment of POME Using Acidified Process

Acidified Palm Oil Mill Effluent (POME) is generated during the bio-hythane phase as shown in Figure 2.1. A two-stage fermentation process produces bio-hythane, which is made up of hydrogen and methane. Hydrolysis and acedogenesis reactions form the first step, while acetogenesis and methanogenesis make up the second. The optimum pH range for the first level, according to a previous paper, is 5–6, with a hydraulic retention period (HRT) of 1–3 days. Meanwhile, the second stage necessitates a 10–15 day HRT at a pH of 7–8, which is ideal for methanogenic bacteria (Aziz et al., 2020).

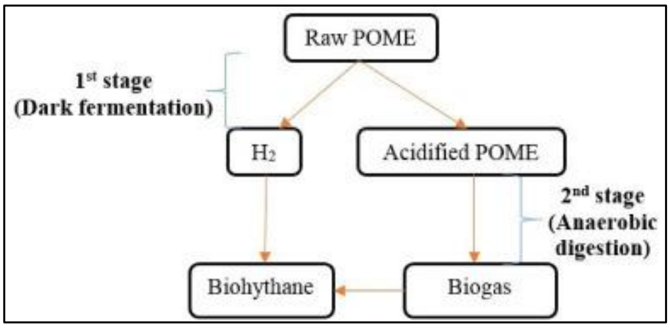

Figure 2.1 Biogas production from acidified POME

Source: A Aziz et al., (2020)

POME is used to manufacture hydrogen in the first step, and the digestate produced is acidified POME with a high content of volatile fatty acids including butyrate and acetate. The acidified POME is used as a methane-producing substrate, and it has been shown to contain large amounts of biogas. The amount of biogas produced, on the other hand, varies depending on the type of bioreactor used. A continuous stirred tank reactor (CSTR) with a 5-day HRT provided 320 L CH_4/kg chemical oxygen demand (COD), with 94 percent of COD extracted from the acidified POME in some research (Kassim et al., 2020).

While another research used an HRT of 6 days, 315 L CH_4/kg COD was generated in up-flow anaerobic sludge blanket (UASB) reactors for a methane yield with 95 percent COD elimination. Final research that used an anaerobic sequencing batch reactor (ASBR), discovered that the lowest volume of methane released was 260.3 L CH_4/kg COD when the HRT was three days. In this scenario, only 71 percent of COD was deleted. As a consequence, the amount of biogas that can be extracted from acidified POME is affected by the use of a suitable bioreactor and a sufficient HRT (A Aziz et al., 2020).

2.5 Pre-Treatment Using Air Stripping

Air stripping is the process of moving air through contaminated water with volatile contaminants in a treatment system above ground. The air movement from this process causes volatiles to evaporate at a faster rate. Air stripping is not a treatment but just a way to transfer contaminants to one phase from another (Folino et al., 2020).

Current mature leachate treatment procedures include coagulation, air stripping, settling, and flocculation, all of which need considerable financial investment in equipment as well as time-consuming daily maintenance. Biological treatment approaches, as opposed to physical or chemical treatments, are often more efficient and less costly for eliminating leachate contaminants (Xiong et al., 2018).

Suitable ratio for anaerobic digestion were obtained from 80% of ammonia reduction and the increasing of carbon to nitrogen ratio to 25. It led to the significant removal of chemical oxygen demand (COD) and biogas production. it is an efficient biotechnological treatment of highly concentrated organic wastewater such as palm oil mill effluent and environmentally friendly technologies due to the low production of sludge and biogas production (Smaoui et al., 2019).

2.6 Anaerobic Digestion

Anaerobic digestion is recognized as one of the effective ways for food waste processing and coping with agricultural waste and sewage sludge by the country, Defra, the Welsh Assembly, the Scottish Parliament, Friends of the Earth, and the National Farmers. Union. The term anaerobic means "no oxygen." (Jouzani, 2018). Anaerobic digestion for biogas processing occurs in a sealed vessel known as a reactor, which is constructed and built in a variety of shapes and sizes based on the site and feedstock requirements. These reactors involve diverse microbial communities that break down (or digest) waste to create biogas and digestate (the solid and liquid substance end-products of the AD process), which are discharged from the digester (Sarwani et al., 2019).

More than 1,300 anaerobic digestion systems dependent on sewage sludge are in use or under construction around the world. While China and India are at the center of the developing world movement, the developed world's focus is primarily on Western Europe. Biogas production from anaerobic digestion in Europe has increased by 4.5–5.0 percent per year, with Germany becoming the main producer (Hannum et al. 2019). In Malaysia, more than 85 percent of palm oil mills have chosen the ponding method for POME handling, with the remaining mills opting for open digesting tanks. In order to resolve the low removal efficiencies in terms of chemical and biological oxygen demand (COD and BOD), total suspended solids (TSS), and oil and grease (O&G) content in treated POME, as well as many environmental concerns associated with the current POME treatment process, an alternate approach was suggested to improve the treatment process of palm oil mill effluent (POME) (Khadaroo et al., 2019).

Digestion systems are technologically simple, requiring little energy and space. 'High-rate' systems with biomass retention and 'low-rate' systems without biomass retention are the two types of anaerobic treatment systems. The increasing requirement for "green" energy, as well as the significant optimization of anaerobic digestion technology in recent decades, especially the production of modern "high rate" and "co-digestion" systems, have all contributed to this pattern (Gouwanda et al., 2020).

2.6.1 Hydrolysis

A chain of reactions is involved in the anaerobic digestion of POME, primarily hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Hydrolysis is a reaction in which extracellular enzymes from hydrolytic microorganisms break down particulate inorganic compounds or complex molecules, such as sugars, proteins, and lipids, into simpler molecules, such as sugar and amino acid (Khadaroo et al., 2019).

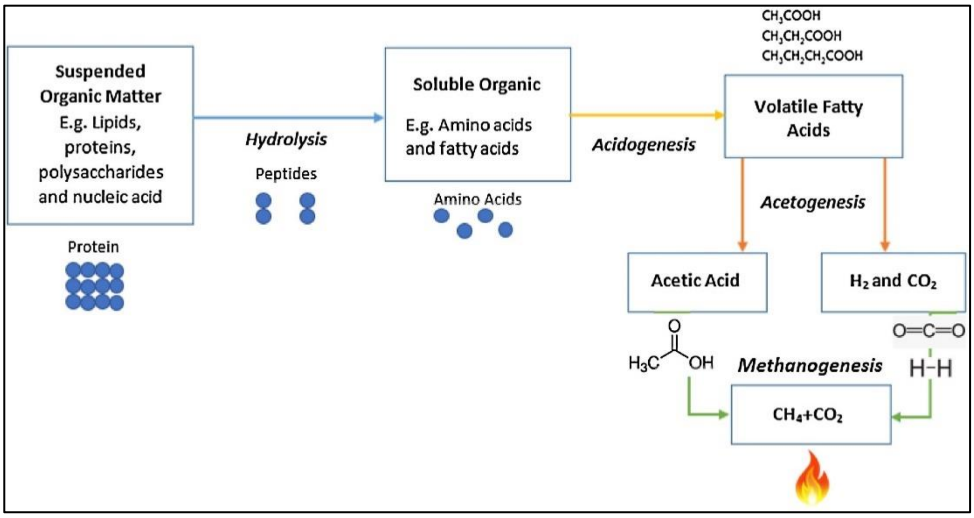

Figure 2.2 Anaerobic Digestion Process
Source: Khadaroo et al., (2019)

Hydrolysis occurs when water is broken down into H+ cations and OH- anions. Larger polymers are often hydrolysed, often in the presence of an acidic catalyst. Since biomass is typically made up of very large organic polymers that are otherwise unusable, hydrolysis is an important first step in anaerobic digestion. These big polymers, such as proteins, fats, and carbohydrates, are broken down into smaller molecules like amino acids, fatty acids, and simple sugars by hydrolysis (Karuppiah., 2019).

2.6.2 Acidogenesis

Acedogenic bacteria break down the hydrolyzed molecules further into organic acids and intermediates, forming acetic acid, carbon dioxide, and hydrogen, as well as inorganic compounds like ammonia and hydrogen sulfide (Khadaroo et al., 2019). When producing ammonia, H2, CO2, H2S, shorter volatile fatty acids, carbonic acids, alcohols, and trace quantities of other by-products, these fermentative bacteria create an acidic atmosphere in the digestive tank. Although acedogenic bacteria continue to break down the organic matter, it is still too large and unusable for the ultimate purpose of creating methane, so the biomass must then go through the acetogenesis process (Karuppiah., 2019).

2.6.3 Acetogenesis

In general, acetogenesis is the formation of acetate, a derivative of acetic acid, from carbon and energy sources by acetogens. Acetogens break down the biomass at a point to which methanogens can use most of the remaining material to produce methane as a biofuel. Acetogenesis is a pre-methanogenesis phase because methanogenic microorganisms can only assimilate acetate, CO2, and H2 among all the products formed during fermentation. A group of unique fermenting bacteria known as acetogenic bacteria converts organic acids of more than two carbon atoms and alcohols, fermentation products, to acetate, CO2, and H2 during acetogenesis (Aquino et al., 2018).

2.6.4 Methanogenesis

Methanogenesis is the final stage of anaerobic digestion, in which methanogens generate methane from acetogenesis's final products as well as some of the intermediate products of hydrolysis and acedogenesis. In methanogenesis, acetic acid and carbon dioxide, the two primary components of the first three stages of anaerobic digestion, are used to produce methane in two different ways:

$$CO_2 + 4\,H_2 \rightarrow CH_4 + 2H_2O \tag{2.1}$$

$$CH_3COOH \rightarrow CH_4 + CO_2 \tag{2.2}$$

Although CO_2 can be transformed into methane and water in the reaction, the acetic acid pathway is the most common method for methane to be formed in methanogenesis. The two primary products of anaerobic digestion are methane and CO_2 (Karuppiah., 2019).

While anaerobic digestion is one of the most cost-effective and promising wastewater treatment processes, it is a complicated and time-consuming technique. The efficiency of anaerobic digestion can be improved even further by implementing a pre-treatment technique into the process. When it comes to wastewater disposal, various categories of pre-treatment methods have been researched over time. Pre-treatment technologies have been shown to improve the anaerobic digestion process by increasing digestion rate, decreasing retention time, and increasing biogas generation (Khadaroo et al., 2019).

2.7 Parameter Test for Effluent

In the early 1970s, the United States Environmental Protection Agency (USEPA) has implemented the Clean Water Act and have demanded every institutional, commercial entity, and industrial to continually improve the quality of their process wastewater effluent discharges (Berle., 2017).

There are four categories which are organics, solids, nutrients, physical properties, and other impact parameters. For organics, it aimed at establishing the relative strength of wastewater such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and Total Solids (TS). For solids, it is a measurement of the concentration of particulate solids that dissolve or suspend in wastewater while nutrients are a measurement of the concentration of targeted nutrients that can contribute to the acceleration of eutrophication. Lastly, analytical tests are designed to measure a varied group of constituents that directly impact wastewater treatability such as temperature, turbidity, and pH (Berle., 2017).

2.7.1 pH

The pH effect is similar to the temperature that helps in the reduction of ammonia nitrogen and enhancing the production of biogas. As the pH content increases, the equilibrium will shift to the right due to the consumption of protons by hydroxyl ions. These shifts will increase the free ammonia in the equation. When pH is higher than the pka of ammonia nitrogen, the concentration of free ammonia is also greater than the concentration of ammonia ions which makes it preferable for the stripping process (Palakodeti et al., 2021).

In the anaerobic digestion process, methanogens are important in producing biogas. A critical factor that impacts methanogens is pH. Methanogens can survive well at an alkaline state of pH. Biogas can only be generated by having and converting the substrates of volatile fatty acids (VFA). The alkalinity in anaerobic digestion must be adequate for having sufficient buffer capacity at resisting the pH changes due to the presence of VFAs (Choong et al., 2018).

2.7.2 Ammonia Nitrogen

Ammonia is dangerous to the environment but also a renewable energy source of energy that needs a solution for the recovery of ammonia. Various techniques have been studied to recover ammonia from organic waste streams including ion exchange, electrodialysis, gas-liquid stripping, adsorption, and membrane separation. From all of these, the air stripping pre-treatment process is one of the treatments that are low in cost which helps in reducing the ammonia content in wastewater (Palakodeti et al., 2021).

Ammonia removal is mainly carried out at high temperature or/and pH content. The equilibrium shifts towards the gaseous phase, followed by ammonia stripping. The pH content coupled with agitation and turbulence of solution can result in the conversion of solution in the conversion of ammonium to volatile ammonia. The amount of air passing through the stripping process will promote the transition of ammonia from the liquid phase to the air bubble surface area for gas desorption (Ulu & Kobya, 2020).

High removal of ammonia nitrogen is helping in enhancing biogas production through anaerobic digestion. Organic nitrogen in the form of proteins, uric acids, and amino acids during anaerobic digestion is hydrolyzed to inorganic ammonia. Its process is slow and the ammonia released tends to accumulate (Krakat et al., 2017).

METHODOLOGY

3.1 Introduction

This chapter focused more on the process to produce biogas starting from the air stripping pre-treatment process, laboratory for ammonia nitrogen, and lastly anaerobic digestion. This chapter will describe the method, instruments, and materials used in this experiment to produce biogas from anaerobic digestion of Palm Oil Mill Effluent (POME) by ammonia removal by using air stripping pre-treatment. The samples were collected from the first effluent pit at Felda Lepar Hilir 3 Palm Oil Mill, Gambang, Kuantan, Pahang, Malaysia, and was adjusted its pH content from acidic to alkaline before undergoing air stripping pre-treatment process and anaerobic digestion process. The bottles contain 550 ml of adjusted pH of POME and one bottle of raw POME were undergoes an air stripping pre-treatment process for 1, 2, 3, and 4 days before continuing with anaerobic digestion for biogas production. 50 ml from the samples were taken to the environmental laboratory to check the reduction of ammonia nitrogen. At the end of the experiment, the ammonia nitrogen of POME before and after pretreatment was compared and the biogas production of the treated bottle and control bottle were compared to identify the optimum pH and HRT of air stripping pre-treatment to increase the production of biogas. The overview of the experiment was constructed in the flowchart as shown in Figure 3.1.

3.2 Flowchart

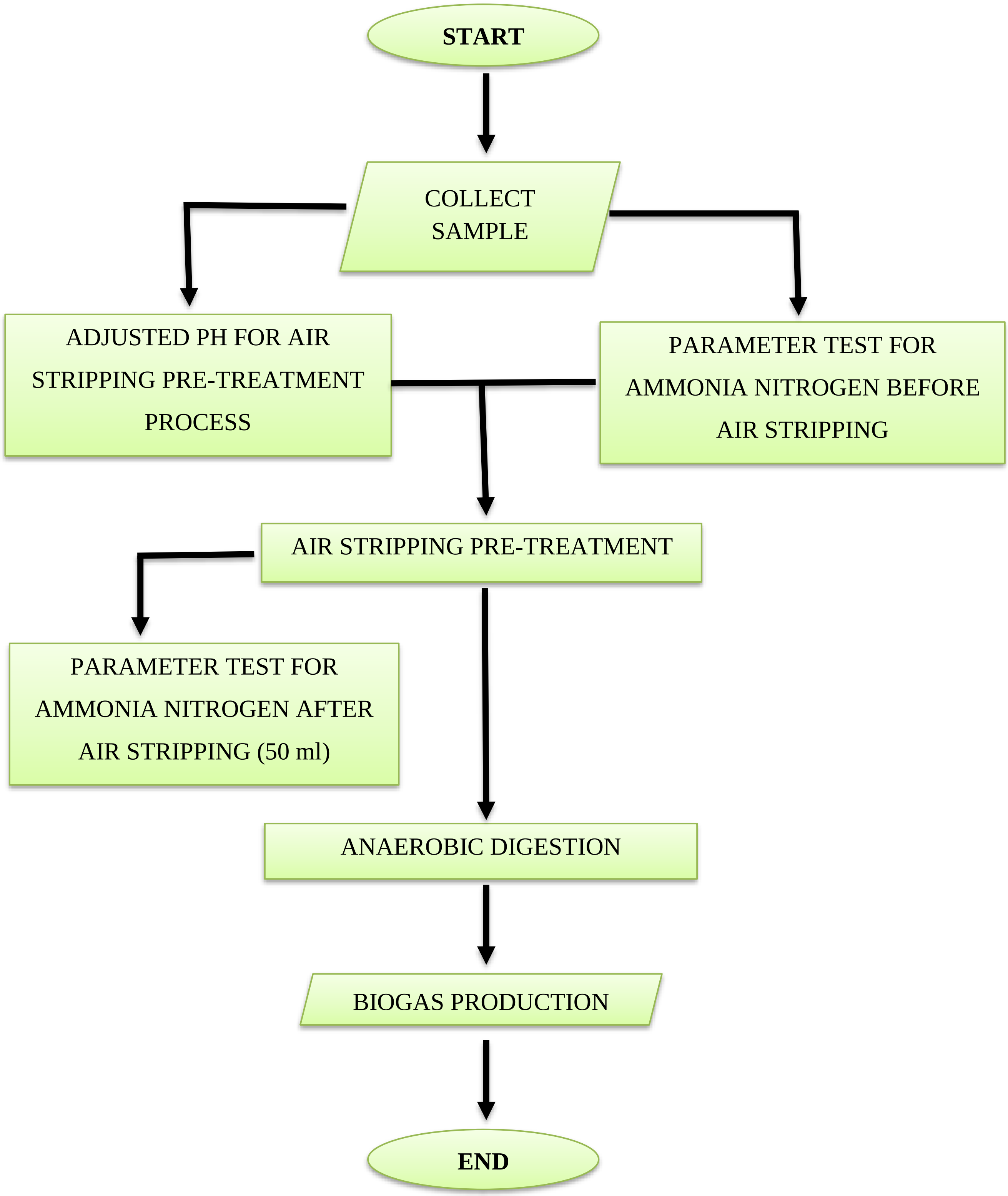

Figure 3.1 Methodology Flowchart

3.3 Materials

- Power head pump (Aerator)
- Nalophan bag
- Water Heater
- Bottle glass
- 25L tong
- Box container
- Silicon tube
- Hot glue gun
- Hot glue stick
- Funnel
- DR 5000 Spectromotormeter

3.4 Parameter Test for Effluent

POME is a thick brownish liquid that contains high amounts of total solids, oil and grease, Chemical Oxygen Demand (COD), and Biochemical Oxygen Demand (BOD). A few analytical tests have been developed and are used to determine the concentration (typically in milligrams per liter, mg/L, or the equivalent unit of parts per million, ppm) of the various forms of solids that can exist within a wastewater sample. There is a test was run in this experiment which is the ammonia nitrogen test.

3.4.1 Ammonia Nitrogen – Standard Method 8155

Figure 3.2 Ammonia Nitrogen Test

Samples over 100mg/l cause carry-over in the samples immediately preceding and following them, and must be diluted below 100mg/l before analysis. Highly colored samples cannot be analyzed by this method (unless the color is diluted out first) as the determination relies on the measurement of the color produced in the analytical reaction. The presence of monochloramine, which may be present in chlorinated water and wastewater, may interfere. The Low-Level method is not suitable for Sea Water, the chloride levels in seawater prevent the development of the color reaction in the low-level method. However, in the high-level method, this effect is removed due to the smaller ratio of sample to reagent effectively diluting out the chloride. The standard methods number for ammonia nitrogen using Salicylate Method is 8155.

The experiment was started by pressing the button 'Restore Program' on the DR 5000 spectrophotometer and inserting number 385 for testing the ammonia nitrogen in the water. 10 ml of blank using dilution water and a sample of POME for pH 8, stripping time of 1 day was set and mixed each with ammonia salicylate powder pillow. The solution was shaken until it dissolves. Then, the timer at the spectrophotometer was pressed and let the timer of 3 minutes begin. After the timer was done, the ammonia cyanurate reagent was put on each blank, and a sample of POME and shaken until it dissolves. The timer was then pressed again for the second time and 15-minute countdown was started. After it was done, the blank was cleaned up before being put inside the spectrophotometer, and button ‘zero’ was pressed. Next, the blank sample was taken out and replaced with the sample to get the reading. This step was repeated with a sample of stripping time day 2, day 3, and day 4 of pH 8, pH 10, and pH 12.

3.5 Air Stripping Pre-Treatment Process

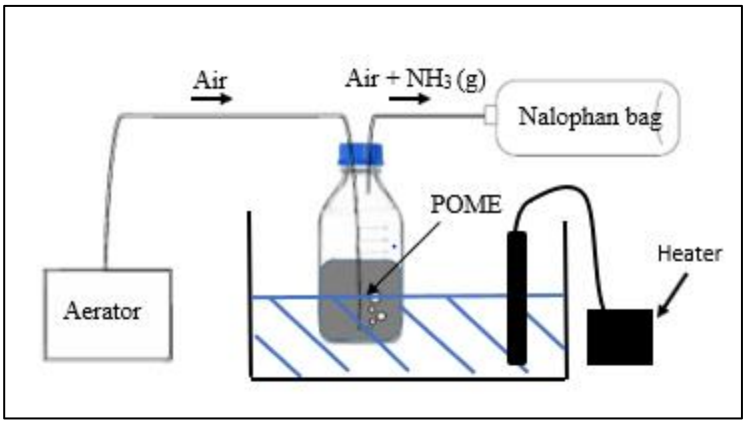

Figure 3.3 Schematic of air stripping experimental setup

In this experiment, the sample was collected from the first pit at Felda Lepar Hilir 3 Palm Oil Mill was first tested for its ammonia nitrogen. Then, the air stripping process was conducted by filling the glass bottle with 550 ml of raw POME. The pH content of the POME was adjusted with the value of 8. The glass bottle was then connected with a nalophan bag and aerator using a silicone tube to supply 4 L/min of airflow rate. The glass bottle containing POME was put inside a water bath with a temperature of 35°C during the air stripping pre-treatment process. The water bath is used to adjust the temperature of the experiments. The nalophan bag is used to trap ammonia gas that arises from the pre-treatment process from release to the environment.

All the connections between the silicone tube with the bottle and the nalophan bag were secured so that there is no gas is being released into the environment. The air stripping pre-treatment process was conducted within 1 day of stripping time. After that, the treated POME was tested for its Ammonia Nitrogen content. Then, the results of the parameter test before and after the air stripping pre-treatment process was compared. The air stripping pre-treatment process was repeated with different pH value which is 10 and 12 and different stripping time which is 2, 3, and 4. An operational condition of pH value from 8 to 12 with 24 hours of HRT can remove up to 97% of ammonia nitrogen in POME. Apart from that a high ammonia removal can be achieved at a high flow rate, between 4 and 10 L/min. Figure 3.2 shows the scheme of the experimental setup used for the tests on the systems treating POME.

3.6 Anaerobic Digestion Process

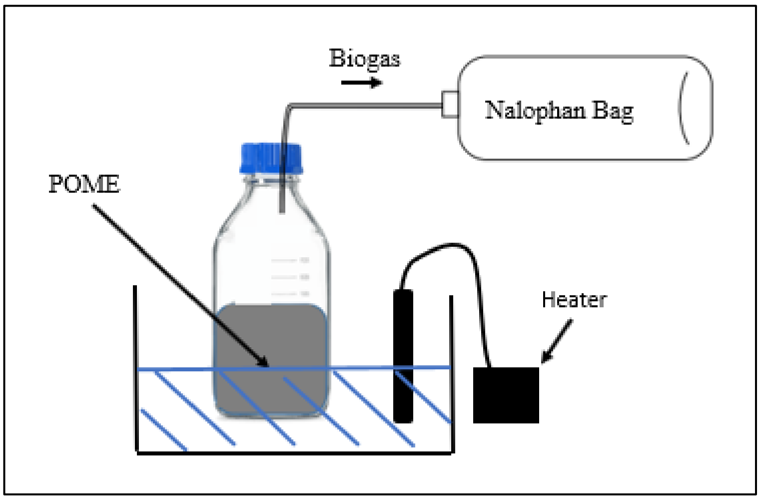

Figure 3.4 Schematic of anaerobic digestion experimental setup

After the pre-treatment of the air stripping process, the bottle was detached from the aerator. During the detachment, the seal was tightly closed to prevent any of the gas from coming out of the bottle. The nalophan bag attached with a silicon tube will be connected to the treated bottle, replacing the air stripping pre-treatment process. The bottle was sitting for 7 days Hydraulic Retention Time (HRT) and was operated at room temperature around 35°C. The glass bottle containing POME was put inside a water bath with a temperature of 30°C during the anaerobic digestion process. Within that time, the nalophan bag was expanded according to the collection of biogas production. Another bottle containing 550 ml of raw POME was set in an anaerobic digestion process without the air stripping pre-treatment process and this bottle will be used as a control bottle. The condition of the anaerobic digestion of the control bottle will be the same as the treated bottle.

3.7 Water Displacement Method

For the final step, the biogas production will be measured by using a conventional method which is the water displacement method. Water displacement is a method used to capture gases that are insoluble in water. The biogas in the nalophan bag is generated from the glass bottle and collected by filling another container with water. The generated biogas will replace the water by pressing the nalophan bag and water will slowly come out from the container since no element can occupy the same space at the same time as shown in Figure 3.4.

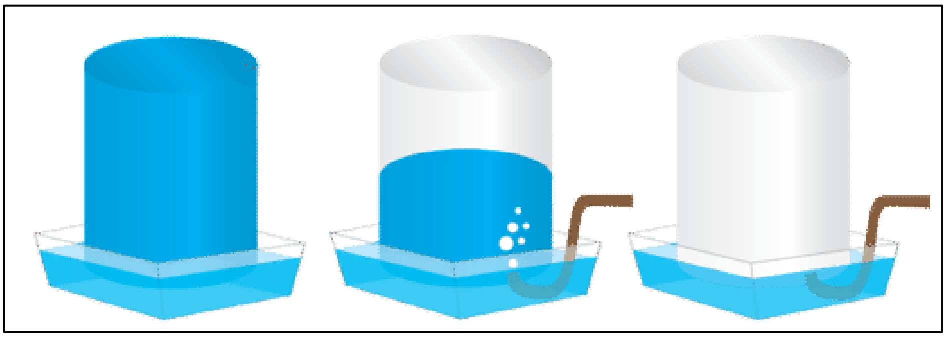

Figure 3.5 Water Displacement Process

The following formula was used to calculate the rate of biogas production collected in the anaerobic digestion process.

$$\text{Volume of dry biogas} = \text{Volume water before} - \text{Volume water after pressing nalophan bag} \quad 3.1$$

$$\left(\frac{P_1 v_1}{T_1}\right) = \left(\frac{P_2 v_2}{T_2}\right) \quad 3.2$$

$$Rate\ of\ Wet\ Biogas\ Production = \frac{Volume\ of\ Wet\ Biogas\ Production\ (ml)}{Time\ taken\ (h)} \quad 3.3$$

$$Rate\ of\ Dry\ Biogas\ Production = \frac{Volume\ of\ Dry\ Biogas\ Production\ (ml)}{Time\ taken\ (h)} \quad 3.4$$

All the parameters of effluent which is ammonia nitrogen inside the treated POME also will be tested. The result of the treated bottle will be compared with the control bottle. The comparison includes the percentage of ammonia removal and the percentage of biogas production and the parameter of effluent before and after the treatment process. This process then will be repeated by using the value of pH 10 and 12 for air stripping pre-treatment. All of the data will be recorded, and the results will be compared to choose the best parameter for reducing ammonia nitrogen removal and the highest amount of biogas production.

RESULTS AND DISCUSSION

4.1 Introduction

This study aims to enhance the quality of biogas by using the air stripping process to treat palm oil mill effluent (pome). The result of the research is analysed in this chapter in detail. The first part of this chapter will explain the result of air stripping to produce quality biogas. Then, the value of ammonia nitrogen before and after air stripping will be compared since the reduction of ammonia nitrogen means the production of biogas is safe for the environment and the quality of the biogas is higher. In the second part, the production of biogas will be monitored through anaerobic digestion and the result will be calculated by using water displacement methods

4.2 Air Stripping and Ammonia Nitrogen

The air stripping process can be conducted as pre-treatment method for anaerobic digestion in removing ammonia nitrogen to increase biogas production. According to Zangeneh et al. (2021), the air stripping process can be used in concentrated wastewater treatment to remove ammonia with high efficiency. Each experiment performed with the volume of pome, flow rate, and temperature is fixed with 550 ml, 4 L/min, and 35°C respectively. Raw sample of pome was analysed before the laboratory research was started. Table 4.1 shows the characteristics of palm oil mill effluent samples before and after the air stripping process.

Table 4.1 Characteristic of Palm Oil Mill Effluent

Parameter	Unit	Raw POME	POME after Air Stripping
pH		4.71	8 – 12
Temperature	°C	45	28 – 35
Ammonia Nitrogen	mg/L	0.42	0.03 – 0.34
Volume of POME	ml	550	400 – 520
Rate of Wet Biogas Production	ml/h	7.619	2.5 – 5.54
Rate of Dry Biogas Production	ml/h	7.20	2.36 – 5.53

The air stripping process is carried out with the duration of one to four days that labelled with Day 1, Day 2, Day 3, and Day 4. In order to make the air stripping process became more effective, the concentration of pH of raw POME was changed from 4.17 as raw and acidic to pH 8, 10, and 12 as alkaline by using NaOH solution. The higher the concentration of pH the higher the reduction of ammonia stripping. This is supported by Palokodeti et al,. (2021) where the concentration pH of a pome is higher than the concentration of ammonia nitrogen making it preferable for effective ammonia stripping.

Table 4.2 Result Analysis for pH = 8, pH = 10, and pH = 12

Stripping Time (day)	pH	Ammonia Nitrogen (mg/L)	
		Before Air Stripping	After Air Stripping
1	8	0.42	0.34
2			0.18
3			0.27

4			0.10
1	10		0.27
2			0.199
3			0.10
4			0.07
1	12		0.11
2			0.09
3			0.07
4			0.03

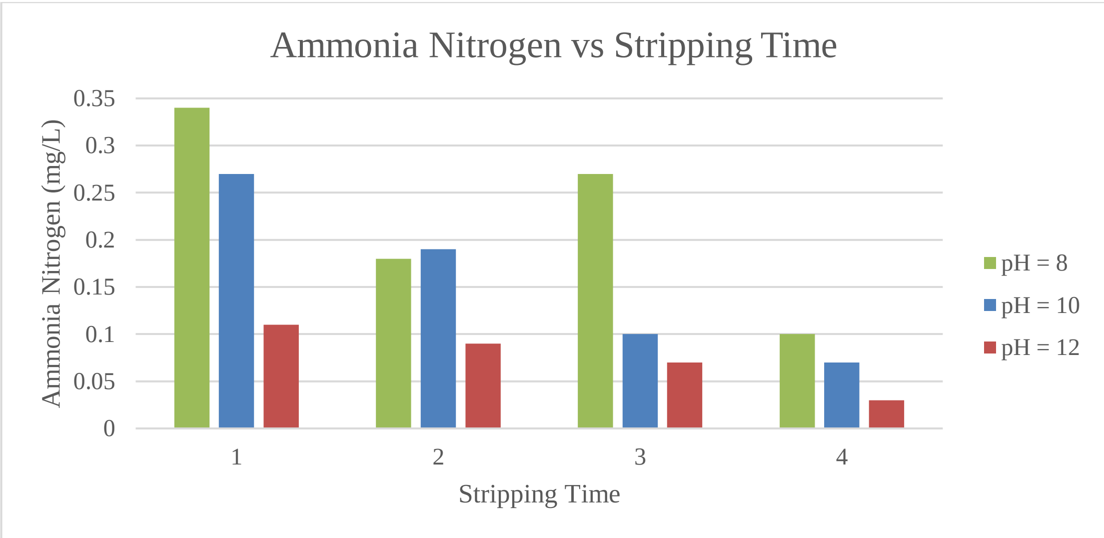

Figure 4.1 Effect of Ammonia Nitrogen Removal for pH 8,10 and 12 with Stripping Time for Day1 to Day 4.

The reduction of ammonia nitrogen and stripping time was investigated to determine the effectiveness of the air stripping process in treating anaerobic digestion for a better quality of biogas production. This is shown through Table 4.2 where the amount of ammonia nitrogen in Day 1 of stripping time is decreased a bit with the value of 0.34 mg/L followed by 0.18 mg/L for Day 2, 0.27 mg/L for Day 3, and 0.10 mg/L for Day 4.

Next, for pH 10, the reduction of ammonia nitrogen is continually increasing compared to Day 1 pf pH 8 where the result for reduction of ammonia nitrogen is 0.27 mg/L. In Day 2, Day 3 and Day 4, the value is 0.19 mg/L, 0.10 mg/L and 0.07 mg/L respectively.

Lastly, ammonia nitrogen inside the pome with pH 12 shows some reduction compared to the value ammonia nitrogen of raw pome. The result for stripping time Day 1 shows the value of 0.11 mg/L while Day 2 is 0.09 mg/L, Day 3 with 0.07 mg/L, and Day 4 with 0.03 mg/L.

The data collected from all tables are summed up through a graph as shown in Figure 4.1 where the highest removal of ammonia nitrogen is pH 12 with the longest stripping time of four days. According to Santos et al., (2020) air stripping can remove around 92.8% ammonia nitrogen with HRT 4 to 9 days with a high value of pH. Kinidi et al., (2018) also stated that pH becomes insignificant when the pH value exceeded 10.5 but due to the additional NaOH solution, it boosts the process of ammonia nitrogen removal inside the pome.

4.3 Biogas Production

Biogas production can be obtained through a treated anaerobic digestion process. In order to obtain high quality of biogas production, it is affected by a few factors. The factors include hydraulic retention time, pH value, ammonia removal, and volume of pome after the air stripping treatment process. Ammonia removal is successfully achieved through the air stripping process with the proper pH value and the duration of stripping time. This is supported by Kinidi et al., (2018) where a high reduction of ammonia removal can enhance the performance of the anaerobic digestion process thus boosting the production of biogas.

However, the air stripping process also has a disadvantage since it is a process where it flows the moving air with a certain flow rate through contaminated water such as pome, chicken manure, and wastewater (Ulu & Kobya, 2020). Due to this, it evaporated water into gases making the volume of pome decrease from 550 ml in its original state to 400 ml depending on the duration of the stripping time. As a result, it affected the collection of biogas production since the volume of anaerobic digestion required is inadequate. The calculation of the raw pome rate of wet and dry biogas production is shown below.

1) Volume of Raw Wet Biogas Production

Temperature inside the glass bottle, T1 = 35 °C @ 308.15 K
Pressure inside the glass bottle, P2 = 101.3 kPa
Volume of biogas production (Water displacement method), V1 = 1280 ml

2) Volume of Raw Dry Biogas Production

Temperature inside the glass bottle, T2 = 35 °C @ 308.15 K
Water Pressure at 308.15K (P_{water}) = 5.63 kPa
Total Pressure (P_{water} + P_{biogas}) = 101.3 kPa
Biogas Pressure ($P_{biogas} = P_{total} – P_{water}$), P1 = 95.67 kPa

To calculate the volume of dry biogas production, the combination of Boyle's and Charles's Laws was used.

$$\left(\frac{P_1 v_1}{T_1}\right) = \left(\frac{P_2 v_2}{T_2}\right)$$

$$\left(\frac{(95.67\ kPa)(1280\ ml)}{308.15\ K}\right) = \left(\frac{(101.3\ kPa)(v_2)}{308.15\ K}\right)$$

$$v_2 = \frac{(95.67\ kPa)(1280\ ml)(308.12\ K)}{(308.15\ K)(101.3\ kPa)}$$

$$v_2 = 1208.86\ ml$$

3) Rate of Raw Wet Biogas production

$$Rate\ of\ Wet\ Biogas\ Production = \frac{Volume\ of\ Wet\ Biogas\ Production\ (ml)}{Time\ taken\ (h)}$$

$$Rate\ of\ Wet\ Biogas\ Production = \frac{1280\ ml}{(7\ days\ x\ 24\ hours)}$$

$$Rate\ of\ Wet\ Biogas\ Production = 7.62\ ml/h$$

4) Rate of Raw Dry biogas production

$$Rate\ of\ Dry\ Biogas\ Production = \frac{Volume\ of\ Dry\ Biogas\ Production\ (ml)}{Time\ taken\ (h)}$$

$$Rate\ of\ Dry\ Biogas\ Production = \frac{1208.86\ ml}{(7\ days\ x\ 24\ hours)}$$

$$Rate\ of\ Dry\ Biogas\ Production = 7.20\ ml/h$$

Table 4.3 Biogas Production of pH = 8, pH = 10, and pH = 12

Stripping Time (day)	pH	Rate of Biogas Production (mL/h)		
		Raw POME	Wet Biogas Production	Dry Biogas Production
1	8	7.62 (Wet Biogas) 7.20 (Dry Biogas)	3.81	3.60
2			2.86	2.70
3			3.04	2.87
4			2.50	2.36
1	10		4.64	4.38
2			3.93	3.71
3			2.68	2.53
4			3.15	2.98
1	12		5.54	5.23
2			3.63	3.43
3			4.299	4.05
4			3.39	3.20

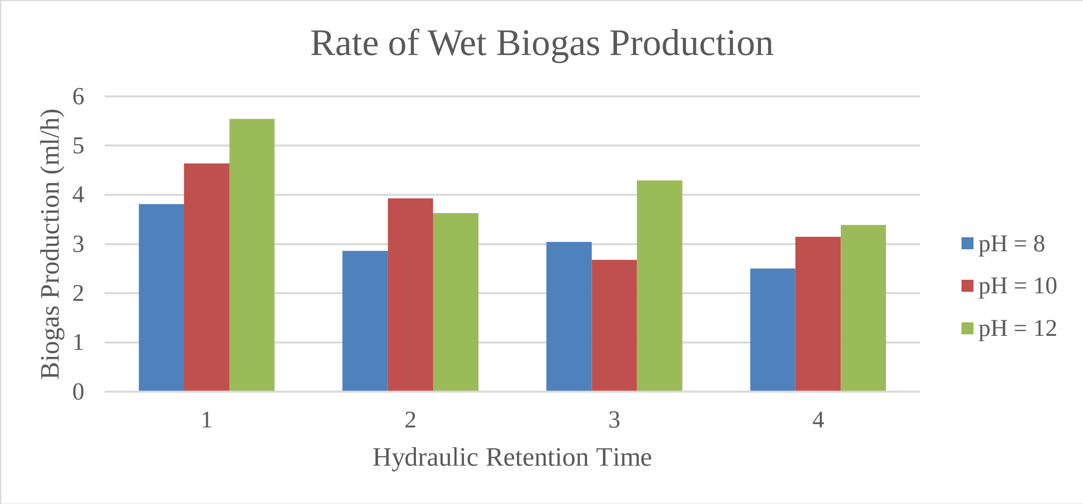

Figure 4.2 Rate of Wet Biogas Production

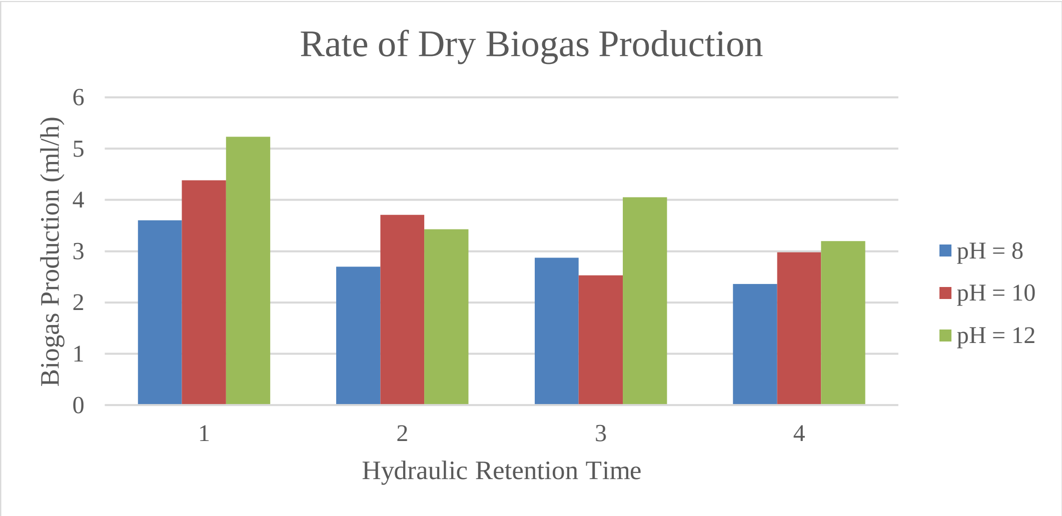

Figure 4.3 Rate of Dry Biogas Production

Biogas production is depending on the hydraulic retention time plus the rate of ammonia removal. The longer the retention time, the lesser the rate of biogas was produced but contain high-quality gases since the efficiency of the ammonia removal is high. This is supported by Fakkaew & Polprasert, (2021) where the quality of biogas produced through treated anaerobic digestion process is higher but the production is lesser compared with shorter retention time.

According to (Loh et al., 2017), 1 m^3 of pome can produce around 28 m^3 of biogas. On the laboratory scale, it can produce around 0.00040 m^3 and above. For this research, the minimum volume of wet and dry biogas collected is at pH = 8 and HRT = 4 as shown in Table 4.3.1 is 420 ml and 396.66 ml respectively. The highest data collected is at Table 4.3.3 with pH=12 and HRT 1 where the volume of wet biogas production is 930 ml and 878.31 ml for the volume of dry biogas production. This is supported by Shi et al., (2017) where shorter HRT is desirable as it is directly related to the reduction of capital cost and the increase of process efficiency.

CONCLUSION

5.1 Introduction

The main objective of this research is to produce biogas production using air stripping as a pre-treatment process in anaerobic digestion. In this chapter, the production of biogas from palm oil mill effluent (POME) is concluded. From this research, raw POME will undergo an air stripping pre-treatment process in enhancing biogas production by the anaerobic digestion process. The conditions for biogas production are as followed: volume of sample is 550 ml, water bath temperature is 35 °C, the air flow rate is 4 L/min, pH content from 8 to 12, stripping time from 1 day to 4 days and hydraulic retention time (HRT) is 7 days. The ammonia nitrogen was highly reduced and biogas production was collected.

5.2 General Conclusion

The objective of this study to reduce ammonia nitrogen in the air stripping pre-treatment process for anaerobic digestion of Palm Oil Mill Effluent (POME) was achieved. The ammonia nitrogen was greatly reduced up to 92.8%. The ammonia nitrogen before the air stripping pre-treatment process was conducted was 0.42ml but after undergoing air stripping for about 1 day, 2 days, 3 days, and 4 days, the data collected was 0.03 ml. From the data, it can be concluded that the air stripping pre-treatment process can reduce the ammonia nitrogen in POME content.

Next, the objective to identify the amount of biogas in anaerobic digestion by providing the best stripping time and pH of POME in the air stripping pre-treatment process was also achieved. Based on the data collected in chapter 4, stripping time day 1 and pH 12 contribute the highest in biogas production and reduction of ammonia nitrogen. The highest biogas production collected was 5.54 ml/h. However, the biogas production produced from the process in stripping time day 1 is not of high quality compared to stripping time day 4 due to shorter stripping time 4. The highest quality of biogas production can be obtained in stripping time 4 due to high ammonia nitrogen reduction. It can be concluded that the longer the stripping time along with high pH content, the higher the quality of biogas production of palm oil mill effluent. Air stripping pre-treatment process also proved in reducing the greenhouse gas that gives a harmful effect towards the environment by reducing the ammonia nitrogen inside POME content. Great reduction of ammonia nitrogen provides much safer and cleaner methane gas inside the biogas production thus contributes to a clean energy resource.

5.3 Recommendation

To improve this study, a few recommendations were suggested. First, the storage of sample after the changes in pH should not be stored for too long to avoid the sample from being damaged. It can affect the laboratory result for the ammonia nitrogen test. It is recommended to use fresh POME every time the air stripping pre-treatment process is conducted to get a better result. Next, to produce more biogas, the temperature of the water bath can be increased up to 50 °C. This is because anaerobic digestion is undergone at high temperatures. This research only uses the temperature of 35 °C for safety purposes. However, it can be improved by using high temperatures with frequent observations. Lastly, the catalyst can be added such as cobalt and nickel can be added during the anaerobic digestion process to stimuli the bacterial inside the sample. it can enhance the production of biogas of palm oil mill effluent.

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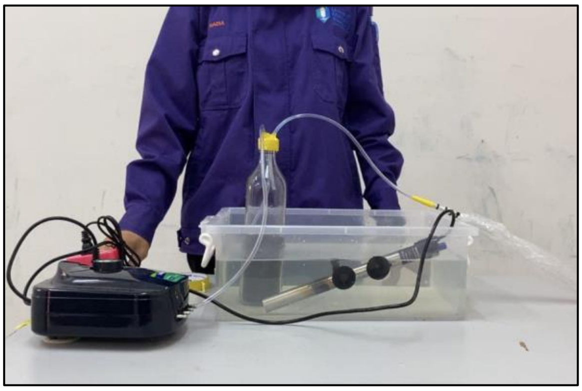
APPENDICES

Appendix A: Picture of Project

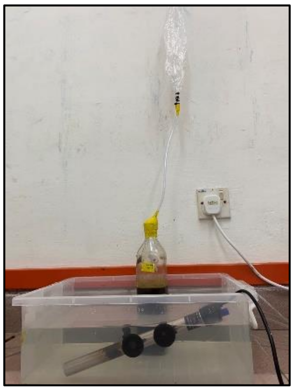
Collect Raw POME at the First Pit

Adjusting pH from Acidic to Alkaline



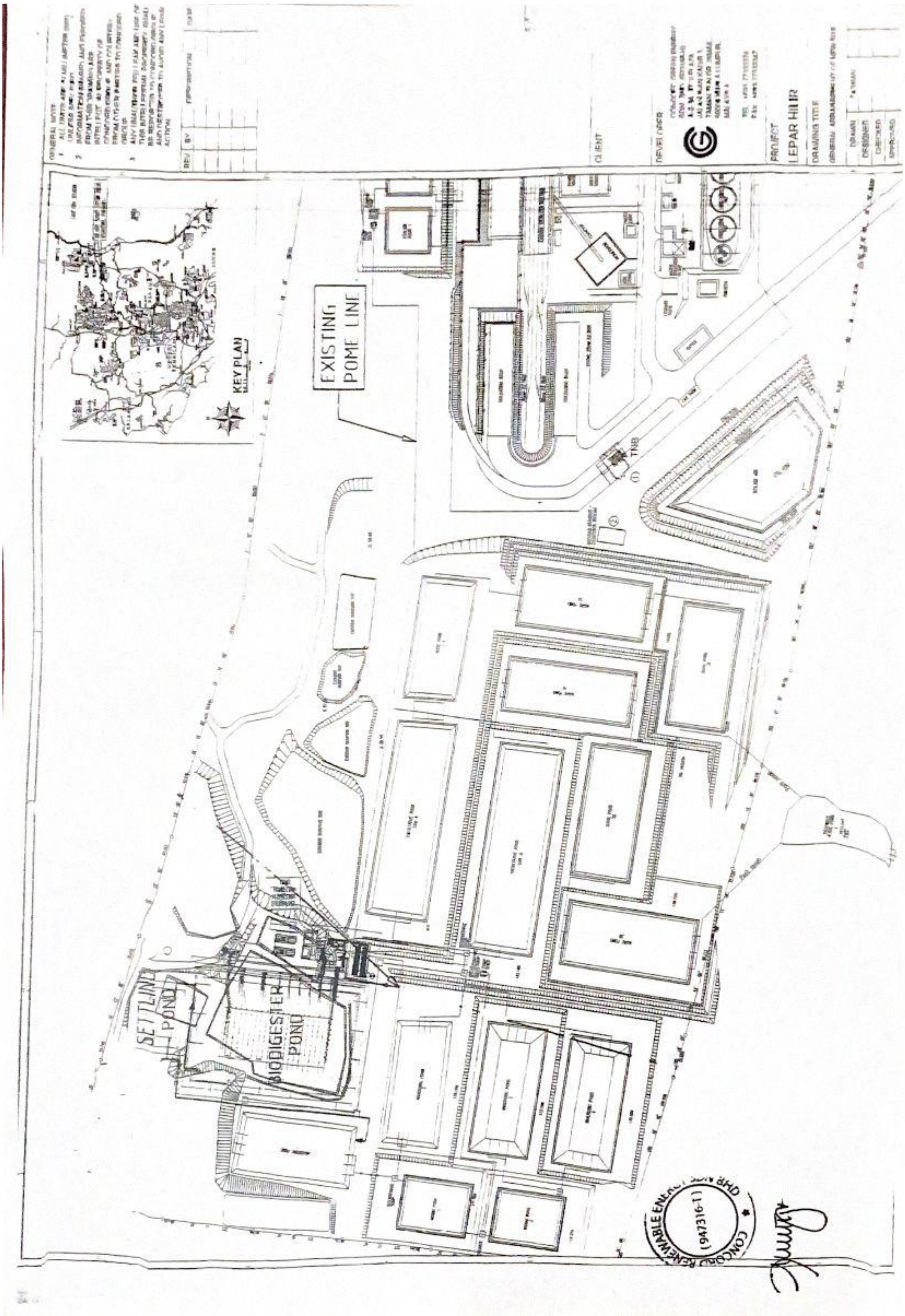
Air Stripping pre-treatment process

Ammonia Nitrogen Test

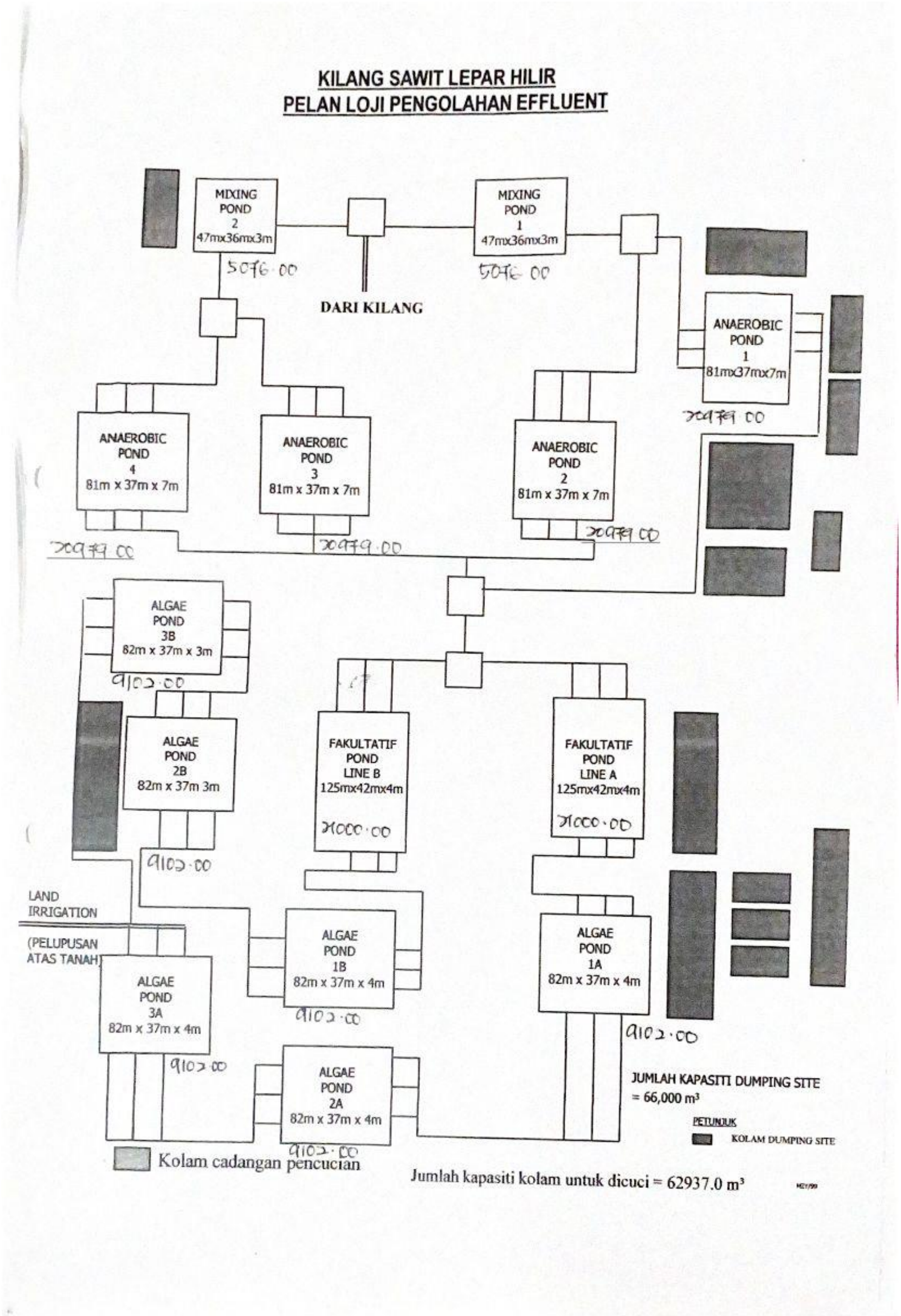


Anaerobic Digestion Process

Appendix B: Lepar Hilir Palm Oil Plan



PLAN A


KILANG SAWIT LEPAR HILIR
PELAN LOJI PENGOLAHAN EFFLUENT
MIXING POND 2 47mx36mx3m
5076.00
MIXING POND 1 47mx36mx3m
5076.00
DARI KILANG
ANAEROBIC POND 1 81mx37mx7m
20979.00
ANAEROBIC POND 4 81m x 37m x 7m
20979.00
ANAEROBIC POND 3 81m x 37m x 7m
20979.00
ANAEROBIC POND 2 81m x 37m x 7m
20979.00
ALGAE POND 3B 82m x 37m x 3m
9102.00
ALGAE POND 2B 82m x 37m 3m
9102.00
FAKULTATIF POND LINE B 125mx42mx4m
21000.00
FAKULTATIF POND LINE A 125mx42mx4m
21000.00
LAND IRRIGATION
(PELUPUSAN ATAS TANAH)
ALGAE POND 1B 82m x 37m x 4m
9102.00
ALGAE POND 1A 82m x 37m x 4m
9102.00
ALGAE POND 3A 82m x 37m x 4m
9102.00
ALGAE POND 2A 82m x 37m x 4m
9102.00
JUMLAH KAPASITI DUMPING SITE = 66,000 m³
PETUNJUK
KOLAM DUMPING SITE
Kolam cadangan pencucian
Jumlah kapasiti kolam untuk dicuci = 62937.0 m³

PLAN B