
# OPTIMIZATION OF BIOGAS PRODUCTION FROM PALM OIL MILL EFFLUENT UNDER THE EFFECT OF SOLID RETENTION TIME, ORGANIC LOADING RATE AND HYDRAULIC RETENTION TIME

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Bachelor of Engineering with Honours

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This project report entitled "**Optimization of Biogas Production from Palm Oil Mill Effluent under the Effect of Solid Retention Time, Organic Loading Rate and Hydraulic Retention Time**," was prepared by Finnegan Tinggie Dampa Anak Inging (50514) is hereby read and approved by:

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Prof Dr. M. Shahidul Islam Date:

Project Supervisor

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FINNEGAN TINGGIE DAMPA ANAK INGING

A dissertation submitted in partial fulfilment

of the requirement for the degree of

Bachelor of Engineering with Honours

(Mechanical and Manufacturing Engineering)

Faculty of Engineering

Universiti Malaysia Sarawak

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For my beloved father, mother,

Brothers, sister and friend

Thanks for everything.

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# ABSTRACT

The aim of this study is to evaluate the effects of organic loading rate (OLR), solid retention time (SRT) and hydraulic retention time (HRT) on the production of biogas from POME. POME that has been left untreated can cause serious damage to the environment around it. This study will explore the potential of biogas production of POME in anaerobic digestion. Anaerobic digestion of POME is where the bacteria will convert organic compounds into biogas without the presence of oxygen. At the same time, in anaerobic digestion will also remove compounds from the palm oil mill effluent, hence, treating the effluent. This study is conducted using an anaerobic bioreactor. This research is carried out at HRT of 4 to 10 days, SRT ranging at 10 to 22 days and OLR of 2-20 gVSS/Ld. Under all the following conditions, the anaerobic bioreactor operates for 30days. The volume of the biogas produced are collected from the bioreactor. The optimum value of biogas produced under all the input of conditions are 3.8L/d. The treatment of POME in anaerobic digestion has been proven to be successful process to treat POME, this is due to because it can significantly reduce damage to the environment and potentially becoming a source of renewable energy in the form of methane gas.

# ABSTRAK

Tujuan kajian ini adalah untuk menilai kesan kadar pengambilan organik (OLR), masa pengekalan pepejal (SRT) dan masa pengekalan hidraulik (HRT) terhadap pengeluaran biogas dari POME. POME yang tidak dibiarkan tidak boleh menyebabkan kerosakan serius terhadap alam sekitar di sekelilingnya. Kajian ini akan meneroka potensi pengeluaran biogas POME dalam pencernaan anaerobik. Pencernaan anaerobik POME adalah di mana bakteria akan menukar sebatian organik ke biogas tanpa kehadiran oksigen. Pada masa yang sama, dalam pencernaan anaerobik juga akan mengeluarkan sebatian dari efluen kilang minyak sawit, oleh itu, merawat efluen. Kajian ini dijalankan menggunakan bioreaktor anaerob. Kajian ini dijalankan di HRT 4 hingga 10 hari, SRT antara 10 hingga 22 hari dan OLR 2-20 gVSS/Ld. Di bawah semua syarat berikut, bioreaktor anaerobik beroperasi selama 30 hari. Jumlah biogas yang dihasilkan dikumpulkan dari bioreaktor. Nilai optimum biogas yang dihasilkan di bawah semua input syarat adalah 3.8L/d. Rawatan POME dalam pencernaan anaerobik telah terbukti menjadi proses yang berjaya untuk merawat POME, ini kerana ia dapat mengurangkan kerosakan terhadap alam sekitar dan berpotensi menjadi sumber tenaga boleh diperbaharui dalam bentuk gas metana

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| | |
|---|---|
| 3D | 3 Dimensional |
| ANOVA | Analysis of Variance |
| BOD | Biochemical Oxygen Demand |
| C/N | Carbon to Nitrogen Ratio |
| CCD | Central Composite Design |
| COD | Chemical Oxygen Demand |
| CPKO | Crude Palm Kernel Oil |
| CPO | Crude Palm Oil |
| CQAs | Critical Quality Attributes |
| DOE | Department of Environmental |
| DoE | Design of Experiment |
| EGSB | Expanded Granular Sludge Bed |
| FFA | Free Fatty Acid |
| FFB | Fresh Fruit Bunches |
| GHG | Greenhouse Gases |
| GLS | Gas-Liquid-Solid |
| HRT | Hydraulic Retention Time |
| MPOB | Malaysian Palm Oil Board |
| MTDP | Maximum Target Desired Profile |
| NGOs | Non-Governmental Organization |
| OLR | Organic Loading Rate |
| pH | Potential of Hydrogen |
| POME | Palm Oil Mill Effluent |
| PVC | Polyvinyl Chloride |
| RSM | Response Surface Method |
| SRT | Solid Retention Time |
| UASB | Up-Flow Anaerobic Sludge Blanket |
| USSB | Up-Flow Staged Sludge Bed |
| VFA | Volatile Organic Compound |
| VOC | Volatile Organic Compound |

| | |
|---|---|
| VSS | Volatile Suspended Solid |
| WtR | Water to Resource |

# CHAPTER 1

# INTRODUCTION

## 1.0 Introduction

This report is on FYP which aims to address the issue in the palm oil mill effluent (POME) and biogas production optimization from POME. This study is conducted to apply the knowledge of Operations Research in engineering to contribute to achieve social, economic, and environmental sustainability. POME can no longer be regarded as a harmful effluent as reported by many researches. POME can be categorised as a form of resource in which it provides countless benefits towards the palm oil industry itself. In this study, POME is treated in an anaerobic condition to produce biogas. The findings of this study will also contribute to producing biogas which bring benefits to environment. Eventually, this study will certainly add new knowledge into the advancement of converting biomass and organic materials of POME into useable energy.

## 1.1 Background of Study

The palm oil mill is one of the major industries in Malaysia and it is growing rapidly to become as a significant agriculture-based industry for contributing to Malaysian economy. Malaysia is the second largest in palm oil industries of the world. The total productions of crude palm oil in 2015 and 2016 are shown is Table 1.1

Table 1.1: Crude oil palm production of Malaysia in 2015 and 2016 (MPOB, 2015, 2016).

| Month | 2015 (tonnes) | 2016 (tonnes) |
|---|---|---|
| January | 1,160,687 | 1,129,747 |
| February | 1,121,628 | 1,042,904 |
| March | 1,495,151 | 1,219,449 |
| April | 1,693,425 | 1,301,291 |
| May | 1,810,530 | 1,364,583 |
| June | 1,763,667 | 1,532,613 |
| July | 1,815,634 | 1,585,341 |
| August | 2,051,000 | 1,701,833 |
| September | 1,959,064 | 1,715,085 |
| October | 2,037,466 | 1,677,873 |
| November | 1,653,946 | 1,574,938 |
| December | 1,399,383 | 1,473,717 |
| **Total** | **19,961,581** | **17,319,374** |

The area planted with oil palm is estimated to be 5.64 million hectares in 2015, an increase of 4.6 percent in 2014 compared to 5.39 million hectares. Sabah is still the largest state planted with oil palms, with 27% of the total area planted with oil palms, followed by Sarawak with 26%, while Peninsular Malaysia which accounted for 47%. The palm oil industry provides a source of livelihood to rural families in government land schemes and private small holders, as well as employment opportunities to agricultural workers in estates (Wu, Mohammad, Jahim, & Anuar, 2010). In addition, Malaysia accounts for 12% and 27% of the world's total oil and fat production and exports (Madaki & Seng, 2013b). Malaysia is known as the palm oil and its products ' major producers and exporters. Therefore, sustainability in line with environmental sustainability is important to meet the worldwide need for oils and fats.

## 1.2 Characteristics and Properties of POME

Impacts on the environment is the main concern of non-governmental organizations (NGOs) and government agencies regarding the increase of the palm oil industry. The negative impacts include deforestation, biodiversity loss, indiscriminate burning, water pollution, and severe GHG emissions. Palm oil mill effluent is the most important pollutant from palm oil mills. To obtain crude palm oil (CPO) and other palm oil products, POME is a by-product of processed FFB. POME has been a waste in the palm oil industry in the past. Often POME is discharged into the waterways by the industry. As POME is biodegradable and contains high level COD and BOD. Without

treatment, POME cannot be discharged directly from the mill. This is because POME is acidic in nature and contains residual oil that is not easily separated by the conventional system based on gravity. Sometimes, raw POME can have a BOD and COD level 100 times higher than domestic sewage (Madaki & Seng, 2013).

POME consist of water-soluble components of palm fruits as well as suspended cellulosic materials such as palm fibres, oil, fat, grease, cell walls, organelles, and a variety of carbohydrates, ranging from nitrogenous compounds, organic acids, and small amount of organic and mineral constituents. POME consists of 95 - 96% water, 4 - 5% total solids, 2 - 4% suspended solids, and 0.6 - 0.7% oil and grease. It has been estimated that the production ofx1 tonne of crude oil palm generates about 2.5 - 3.5 $m^3$ of POME (Ahmad et al., 2015; Jefferson et al., 2016). During POME digestion, methane ($CH_4$) and $CO_2$ is generated, which in released into the atmosphere. Both $CH_4$ and $CO_2$ gas emission are regarded as greenhouse gas which are responsible for ozone depletion. Methane gas are 25 times higher in contributing to global warming potentials compare to $CO_2$ , and POME is one of the potential source of methane gas emission.

POME's composition is largely dependent on the season, the quality of the raw material, and the operations being practiced. POME is a thick brownish colloidal mixture of water, oil, and fine suspended solids when it is still fresh. This effluent has 80 -90℃ high temperature. POME contains high amounts of solids (40000 mg/L), oil and grease (6000 mg/L), biochemical oxygen demand (BOD) on average 25000 mg/L and chemical oxygen demand (COD) at 51000 mg/L. The distinctive characteristics of POME are shown in Table 1.2. No chemicals are added during extraction process; hence, the effluent is non-toxic during the process. Due to the presence of organic acids, the pH of the effluent is low during fermentation process in its complex form.