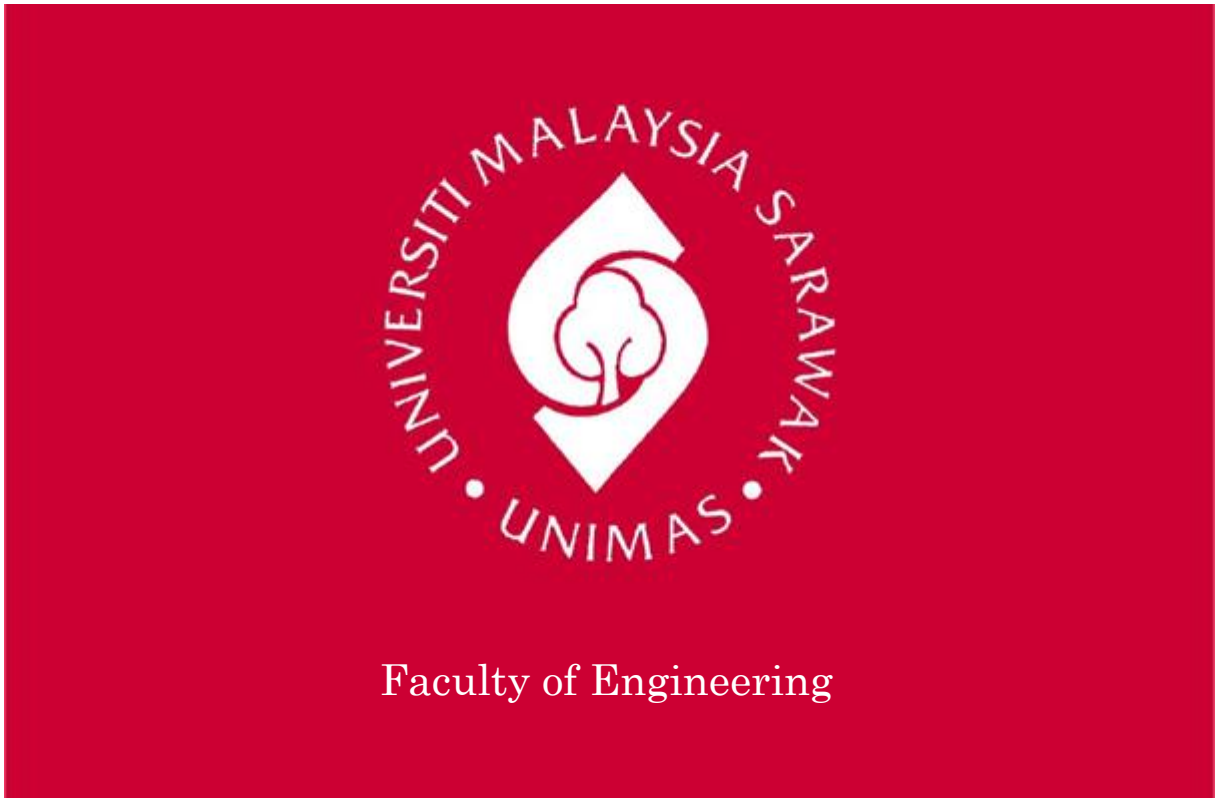

OPTIMIZATION OF BIODIESEL PRODUCED FROM WASTE COOKING OIL AND PALM OIL

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Bachelor of Chemical Engineering with Honours

2022

UNIVERSITI MALAYSIA SARAWAK

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OPTIMIZATION OF BIODIESEL PRODUCED FROM WASTE COOKING OIL AND PALM OIL

NURUL SHAMIMI BINTI ROSLAN

A dissertation submitted in partial fulfilment

of the requirement for the degree of

Bachelor of Engineering (Hons)

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Faculty of Engineering

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Specially dedicated to my family, Roslan Lebak, Nor Faizah Abdullah, and Nurul Shahirah Roslan for their endless support and love, to my cats, Blackie, Grey and Tiger and my friends for being my emotional support system throughout my bachelor journey.

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ABSTRACT

The search for sustainable and environmentally sound alternative for diesel are permanent and biodiesel has been proven to be a viable alternative. Biodiesel is a form of diesel fuel that is sourced and produced from animal fats or plant oils. Numerous plant oils such as palm oil and waste cooking oil have been utilized as feedstock to produce biodiesel. Other than feedstocks, there are also different ways to produce biodiesel, which could affect the yield and quality of the product. The purpose of this project is to produce biodiesel by mixing WCO and another raw material such as palm oil by using two different processes. The two types of processes applied in this study are one step process and three-steps process. One step process includes transesterification, while three-steps process includes pre-treatment, esterification, and transesterification. The quality of the biodiesels produced from the two process differs from one another, hence the biodiesels analyzed by using FTIR. The FTIR process determines the fatty acids that are present in the produced biodiesels. Not only that, but the optimum conditions of factors that influence the production of biodiesel are also optimized. There are several factors that affects the yield of biodiesel, such as methanol to oil ratio, amount of H_2SO_4 and KOH catalyst and palm oil to WCO ratio. Three of the most influential factors were chosen through preliminary lab test and heatmap correlation. The factors were further optimized by using RSM. The sustainability of utilizing WCO to produce biodiesel is also discussed.

Keywords: Biodiesel, waste cooking oil, palm oil, RSM

ABSTRAK

Pencarian alternatif yang mampan dan mesra alam untuk diesel adalah satu proses yang berterusan dan biodiesel telah terbukti sebagai alternatif yang berdaya maju. Biodiesel ialah sejenis bahan api diesel yang dihasilkan daripada lemak haiwan atau minyak tumbuhan. Minyak tumbuhan seperti minyak sawit dan sisa minyak masak telah digunakan sebagai bahan mentah untuk menghasilkan biodiesel. Selain daripada itu, terdapat juga cara yang berbeza untuk menghasilkan biodiesel, dan ia boleh memberi kesa kepada kuantiti dan kualiti produk. Tujuan projek ini adalah untuk menghasilkan biodiesel dengan mencampurkan sisa minyak masak dan bahan mentah lain seperti minyak sawit dengan menggunakan dua proses berbeza. Dua jenis proses yang diaplikasikan dalam kajian ini ialah proses satu langkah dan proses tiga langkah. Proses satu langkah merangkumi proses transesterifikasi, manakala proses tiga langkah merangkummi proses pra-rawatan, pengesteran dan transesterifikasi. Kualiti biodiesel yang dihasilkan daripada kedua-dua proses adalah berbeza antara satu sama lain, justeru biodiesel dianalisis menggunakan FTIR. Proses FTIR menentukan kandungan asid lemak yang terdapat dalam biodiesel yang dihasilkan. Bukan itu sahaja, malah keadaan optimum faktor yang mempengaruhi pengeluaran biodiesel juga dioptimumkan. Terdapat beberapa faktor yang mempengaruhi hasil biodiesel, seperti nisbah metanol kepada minyak, jumlah mangkin H2SO4 dan KOH dan nisbah minyak sawit kepada sisa minyak masak. Tiga daripada faktor yang paling berpengaruh telah dipilih melalui ujian makmal awal dan korelasi peta haba. Faktor-faktor tersebut dioptimumkan lagi dengan menggunakan RSM. Kemampanan penggunaan sisa minyak masak untuk menghasilkan biodiesel juga dibincangkan.

Kata kunci: Biodiesel, sisa minyak masak, minyak sawit, RSM

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ABBREVIATIONS

GHG	Greenhouse gases
WCO	Waste cooking oil
RSM	Response Surface Methodology
ANN	Artificial Neural Network
BBD	Box Behnken Design
CCD	Central Composite Design
FTIR	Fourier Transform Infrared Spectroscopy
FFA	Free fatty acid
FAME	Fatty acid methyl ester
ASTM	American Society for Testing Materials
ANOVA	Analysis of Variance
LCA	Life Cycle Assessment

NOMENCLATURE

%	Percent
ºC	Degree Celsius
kg	Kilogram
mins	minutes
% w/w	Percentage weight per weight
ml	milliliter
mPt	milli-point

CHAPTER 1

INTRODUCTION

1.0 Introduction

In this chapter, background study, problem statement, objectives, research questions and hypotheses, gap of research as well as scope of study for this research project are explained.

1.1 Background Study

Mundane activities that humans carry out in their daily life such as transportation, electricity, cooking, manufacturing all have one thing in common, it utilizes fuel to function. Fuels (fossil fuel) are the remnants of plants and animals, decomposed in the Earth's crust in which humans must dig deep into the Earth to retrieve (National Geographic Society, 2019). The three most known to represent as the example of fossil fuels are coal, oil, and natural gas. Coal is one of the fossil fuels that can be abundantly found in Sarawak, which makes up to nearly 70% of the coal reserves for Malaysia (Meng, 2014). Hence, the electricity that is used by Sarawakian are mainly from the burning of coal in coal-fired plants. This shows how Malaysia consume and demand for coal for the generation of electricity and others.

Moving on, Malaysia is the second largest producer when it comes to petroleum and natural gas in the whole Southeast Asia (EIA, 2021). In 2019, petroleum and natural gas became the two most consumed primary energy in Malaysia with the percentage of 37% and 36% respectively (EIA, 2021). British Petroleum (2020) stated that the oil consumption of the world grew by 0.9 million barrels per day while natural gas consumption increased by 78 billion cubic meters. China and the United States of America were the two main countries that cause the increasing demand of petroleum and natural gas. Petroleum and natural gas are commonly used in fuel stations to provide electricity to the homes of many and provides warmth used for cooking and heating (Shell, 2020). On the other hand, petroleum is commonly used to produce

gasoline, anesthetic, and tires (National Geographic Society, 2018). Hence, it is apparent at how fossil fuels are heavily used and intertwine with human lives.

In spite of fossil fuels and their multitudes that eases and aid human in their day-to-day tasks, the ramification of what fossil fuels had done and still are doing to our planet were simply hard to overlook. The burning of fossil fuels and the by-product of the combustions are notoriously known to degrade the surroundings air quality. Perera (2017) stated that fossil fuel combustion which sourced from energy production produced dangerous gases such as sulfur dioxides, mercury, black carbon, and polycyclic aromatic hydrocarbons (PAH). These gases are the main culprit for the 85% airborne respirable particulate pollution that affects the young and the sick. National Aeronautics and Space Administration (NASA) (2021) claimed that the burning of fossil fuel had escalated the concentration of greenhouse gases (GHG) which leads to global warming. In addition, due to fossil fuels are not renewable energies, the high demand and consumption of the fuels will cause the depletion rate to escalate. Martins *et al.* (2019) reported that in Europe, by the year 2050, the proven reserves for oil and gas will remain approximately 14% and 18%, respectively, while coal proven reserves will remain 72%. The figures of oil and gas reserves stated are alarming and new and sustainable source of fuel is needed as a replacement. Thus, this is where biofuels are introduced.

Biofuels can be produced from a myriad source of vegetable oil and animal fats (Bhavani & Sharma, 2018) which requires chemical reactions, fermentation, catalysts and heat to breakdown existing components in the vegetable oil and animal fats to produce biofuels (Nunez, 2019). Thilakarathne *et al*. (2021) stated that there are two types of biofuels, primary and secondary. Primary biofuels refer to where the raw material used is in its natural form, such as animal wastes, wood chips, and firewood (Food and Agriculture Organization of the United Nations, 2008). Secondary biofuels refer to where the feedstocks are sourced from plants and microorganisms. Secondary biofuels can be further classified into three generations. The first generation of secondary biofuels is the production of biofuels through fermentation of starch, or transesterification of oil crops. Second generation is bioethanol and biodiesel produced by starch, oils and sugar crops, while third generation biofuels is producing biodiesel and bioethanol from microalgae (Thilakarathne *et al*., 2021). Jeswani *et al.* (2020) reported that third generation biofuels are currently not selected an option as the main

feedstock in producing biofuel as the GHG emissions are considerably higher compared to fossil fuels. Consequently, in this research project, the main feedstock from second generation secondary biofuels poses as a more viable option.

Biofuels are sustainable in the ways that the GHG and hydrocarbon emissions are significantly lower in contrast to the combustion of fossil fuel. One of the examples of biofuels is biodiesel. Biodiesel is a form of diesel derived from plants, animal fats and recycled grease and oil. It has showed potential to reduce air pollution as the biodiesel produced contains lower to no concentrations of aromatic compound and sulfur together with unburned hydrocarbon when combusted (Mohd Sohaimi & Marodzi, 2018). In evidence, the global warming potential for first generation biodiesel were lower as palm oil meets the 60% GHG reduction mark while rapeseed and soya bean almost fulfilling the reduction requirement (Jeswani *et al.*, 2020). Second generation biofuel on the other also confirmed to show lower global warming potential compared to fossil fuel. The second-generation biofuel feedstock such as waste cooking oil is reported to show greater GHG savings, and the global warming potential is 25% lower than standard diesel (Jeswani *et al.*, 2020). Subsequently, the performance of biodiesels to the engine and machine are noted to be considerably better due to the high concentration of octanes and lubricity scoring compounds (Datta *et al.*, 2019).

In the efforts of making the production of biodiesel more sustainable, waste cooking oil (WCO) is proven to be the best option as a feedstock. Due to the ever-surging human population, the consumption of plant and animal oils are also escalating. The heighten of plant and animal oils consumption leads to the increase production of WCO (Goh et al., 2020). WCO is a domestic waste that is produced by the reason of using vegetable oil for cooking and frying food. The WCO is a result of frying and cooking food at a high temperature and serve as a potential source of raw material in producing biodiesel (Zhang et al., 2012). Repurposing WCO to produce biodiesel and avert it from being incorrectly disposed into drains shows that it is a sustainable choice. Besides, the price to obtain WCO are cheaper compared to other viable source to procure as most food industry and household offloads WCO for free or for a small amount of price. Bernama (2021) reported that customers paid RM 1.50 per kilogram (up to 49 kg), RM 1.60 per kilogram (from 50 – 99 kg) and RM 1.80 per kilogram (for more than 100 kg) of WCO.

Additionally, the production of biodiesel from waste cooking oil consists of the a few methods such as direct blend, micro-emulsion process, thermal cracking and transesterification (Mohd Sohaimi & Marodzi, 2018). Conventionally, transesterification method is used in producing biodiesel as it is confirmed to be the simple, cost friendly and only require low pressure and temperature (Vignesh & Barik, 2019). Thilakarathne *et al*. (2021) explained that transesterification is a process where plant or animal oil reacts with alcohol with the presence of an acid or base catalyst to produce alkyl ester and glycerol. Alkyl ester is then separated from glycerol and then purified so that the biodiesel can be obtained. When using WCO as feedstock, extra steps such as pre-treatment and esterification is much needed to filter out leftover food substances and concentration of free fatty acids (FFA) in the used oil (Casallas *et al.*, 2018). By applying pre-treatment and esterification process before transesterification process, the yield and quality of biodiesel are more satisfactory. Certainly, there are other factors that influence the yield and quality of biodiesel other than methods, which are reaction time, reaction temperature, catalyst concentration and methanol to oil ratio (Özgür, 2021).

As mentioned, the factors highly influence the yield and quality of biodiesel, and on that account, the optimum values for the factors must be obtained so that it can be applied to the production of biodiesel. Therefore, Response Surface Method (RSM) is used as a mathematical model for modelling and analysing the optimum value. According to Samuel & Okwu (2019), RSM provides a satisfactory result when it comes to modelling and prediction compared to Artificial Neural Network (ANN). Rizalman & Chen (2020) supports the claim that RSM does better in optimizing the parameters for the production of biodiesel as the coefficient of determination for RSM was much closer to 1 with 0.9959 compared to ANN. Once the optimum temperature is determined, the values are used to produce biodiesel and the characteristics of the biodiesel are examined through Fourier-transform infrared spectroscopy (FTIR). FTIR is a technique that is used to diagnose the composition of a solid, liquid or gas by infrared spectrum (Mohamed Shameer & Mohamed Nishath, 2019)

Hence, this research project aims to produce biodiesel from mixture of WCO and palm oil by using one step process and three-steps process. The characteristics of the biodiesels produced from one step and three-steps process are determine by using

FTIR analysis. The factors that affect the yield of biodiesel are also optimized by using RSM.

1.2 Problem Statement

The most prominent challenge in the production of biodiesel concerns the yield and quality of the biodiesel produced, as well as the source of the raw material used. Biodiesel produced by waste cooking oil have a viable characteristics and quality, however, it is not up to par when compared to the diesel. Quality of biodiesel by using two types of raw materials are proven to be better, compared to utilising only one raw material (Alarcon *et al*., 2017). However, there are little research on mixing two raw materials to produce biodiesel., Moving on, the production of biodiesel also affects the quality of the biodiesel. Samantha & Sahoo (2020) reported that the high content of FFA in WCO deteriorates the quality as the acid value in the biodiesel are high. High acid value in biodiesel leads to corrosion and engine deposits. Hence, the FFA in WCO must be decreased before utilizing it as a raw material for biodiesel production.

Moreover, recent research done by Mimi Suriani Mat Daud *et al.* (2020) stated that there are approximately 50 000 tons of WCO produced yearly in Malaysia. WCO that is not treated or disposed correctly have high possibility of polluting the environment, clog pipes, and wastewater treatment systems and cause death to aquatic life. Majority of the people interviewed are not aware that cooking oil can be recycled and that there are individuals and organization that collects the waste cooking oil. It was found that 45.8% and 46.6% of people in Malaysia dispose WCO by throwing it in the trash and pour into pipe and drains, respectively (Mimi Suriani Mat Daud *et al.*, 2020). In addition, Jafari (2010) stated that oxidation and photochemical reactions will take place as the oil spread on the water surface. This is because the layer of oil on the surface of the water prevents oxygen from entering the body of water, which then leads to the aquatic life present to be deprived off of oxygen.

Moving on, the rate of petroleum depletion in alarmingly rapid, due to the increase of demand from people all around the world. Fuels such as diesel is commonly used in transportation and electricity generation, as it is made from crude petroleum (fossil fuel). This accounts diesel as a non-renewable resource, and since the human population heavily relies on fossil fuel to survive, the possible run out of fuels will

disturb many aspects of life. Diesel engine would no longer operate on the account of diesel's unavailability. Likewise, fossil fuels when burned creates an abundance of pollution, especially air pollution, and this is no exception to the combustion of diesel. EIA (2018) reported that diesel fuel consumption in the United States had given rise to the excessive release of carbon dioxide into the air at 456 million metric tons (Clairotte *et al.,* 2020). A sustainable and environmental-friendly source is to be recommended to promote a secular economy, strengthen energy security, and minimize waste and environmental pollution.

1.3 Research Questions

The research questions are stated below:

a) How much is the yield of the biodiesel produced from one step process and three-step process?
b) How does one step process and three-step process affect the characteristics of biodiesel produced?
c) What are the three most significant parameters that will affect the production of biodiesel the most?

1.4 Research Hypothesis

The research hypotheses are stated below:

a) The yield of the biodiesel produced from one step process and three-step process will differ from one another as different processes are used to produce the biodiesel.
b) The one step process and three-step process affect the characteristics of the biodiesel produced in terms of its FFA content.
c) The three most influential factors that affect the production of biodiesel are methanol to oil ratio, potassium hydroxide (KOH) catalyst amount, and palm oil to WCO ratio.

1.5 Gap of Research

The production of biodiesel from waste cooking oil mainly uses transesterification as one step process method as it shows promising result. Additionally, in order to reach the quality and characteristics of biodiesel that compares to standard diesel but less GHG emission, three-step process with pre-treatment and esterification is proven to be effective (Yaqoob *et al.*, 2021). There is abundance of

research that analyzed the characteristics and yield of one step process and three-steps process but there are only few that compares both biodiesels produced from one step process, and three steps process. In addition, there are only a few journals that researched on the yield of biodiesel produced by mixing two different raw materials, such as WCO and palm oil. Therefore, there are not much evidence that support that mixing two raw materials can improve the quality of biodiesel.

1.6 Research Objectives

The objectives of the research are as stated below:

a) To produce biodiesel from WCO and palm oil by using single step (transesterification) and three step process (pre-treatment, esterification, and transesterification) and compare the properties of both biodiesels.
b) To determine the optimum process by investigating and comparing both of the biodiesel produced from one step process and two-step process using FTIR analysis.
c) To optimize the yield of the biodiesel from three of the most influential factors out of four factors, which are methanol to oil ratio, sulfuric acid (H2SO4) catalyst amount, potassium hydroxide (KOH) catalyst amount, and WCO to palm oil ratio.

1.7 Scope of Study

The main purpose of this research project is to produce biodiesel from waste cooking oil and palm oil int the ratio of 1:1 by using one step process (transesterification) and three-step process (pre-treatment-esterification-transesterification). 1:1 ratio is chosen to determine the effect of equal amount of raw material to the biodiesel quality. Pre-treatment and esterification are used to filter out the leftover food, as well as decrease the water and fatty acid content in the waste cooking oil that may interfere with the quality of the biodiesel. The produced biodiesels from the two types of processes are analyzed by using FTIR, and then the best process is chosen. Moreover, modelling methods such as RSM is applied to determine the optimum values for the chosen and most influential parameters that affects the production of biodiesel. The influential parameters are first chosen through preliminary lab experiments and heatmap correlation. This thesis supports the Sustainable

Development Goals, which are affordable and clean energy (7), responsible Consumption and production (12) and climate action (13)

1.8 Summary

To conclude, the background study and problem statement are discussed to provide basic introduction and understanding towards the research project as well as understanding the problems faced. To understand more on the purpose of this research project, research objective is also stated in this chapter. Last but not least, the gap of research and scope of study explains the boundary of the research area and also specifies the factors that is observed in this project.