OPTIMZATION OF BIODIESEL PRODUCTION FROM AN EDIBLE OIL AND ITS CHARACTERIZATION BY USING RESPONSE SURFACE METHODOLOGY (RSM)

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A report submitted in fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering with Honours

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

APPROVAL

I declare that this report entitled “Optimization of Biodiesel Production from an Edible Oil and its Characterization by Using Response Surface Methodology (RSM)”is the result of my own work except as cited in the reference”.

Signature : ……..……..

Name : …….....

Date : ……

APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor of Mechanical Engineering with Honours

Signature : ……

Supervisor's Name : ……

Date : ……

DEDICATION

I would like to dedicate this project to my esteemed parents Mr. Sharif bin Othman and Mrs. Jamaliah Binti Long, my sagacious supervisor Dr Md Isa bin Ali, passionate family, lecturers, assistant engineers and fellow friends who gave me never ending support, love, encouragement, ideas and pray of day and night throughout this Undergraduate Project.

ACKNOWLEDGEMENT

First and foremost I would like to express my outmost gratitude to Allah S.W.T for giving a chance and opportunity to finish this project. I would also like to express my appreciation to my supervisor, Dr. Md Isa bin Ali for his incredible guidance in terms of practical, psychological support, critical comments and passion along this project duration. Without his valuable helping hand, this work would had not progress smoothly let alone be completed in time limit. Next, I would like to thank my father Sharif bin Othman, my mother Jamaliah binti Long and my brothers Faiz Izwan bin Sharif and Mohd Arif bin Sharif who pave the way and aid me on this project in various other ways, even far before this semester started. Finally, I would like to give thanks to my fellow seniors who provided experienced insight on this project and to my fellow classmates which gives important comments and critiques of the project.

ABSTRACT

The usage of motorized vehicle as a means of transportation have become so important in any daily activities that having a vehicle is normal and a must to possess. Since using vehicles shorten the length of time for transportation, the demand of vehicles generally never decline instead steadily inclining, thus lead to the rise of diesel consumption. However, throughout the year the petroleum reserve dwindle at an alarming rate in which trigger a new race of endeavor of producing an alternative fuel. Biodiesel was discovered to be one of the potential alternative as it could serve the purpose as fuel without remodeling much of the internal engine and release less pollutants. Most of the time, biodiesel is crafted by means of esterification and transesterification process. As for this study, transesterification is applied by mixing methanol and rice bran oil in the presence of sodium hydroxide to produce biodiesel. The three parameters with five level were chosen are reaction temperature, reaction time and molar ratio. Based on these parameter level, the results (biodiesel yield) were optimized by using Response Surface Methodology. The optimized biodiesel or the highest biodiesel yield that was computed by Minitab 18 can be produced by setting the reaction temperature at 45.5 ℃, reaction time of 68.48 minutes and molar ratio of 8.1:1 with constant stirring speed at 400 rpm and 0.6% catalyst concentration. The optimized biodiesel was characterized based on its density which reported to be 0.856 SG or 865 kg/m^3 , viscosity of 7.618 cSt, cloud point of -4.7℃ and pour point at -9.3℃. Meanwhile, the biodiesel yield of the optimized biodiesel was obtained at 88.11%.

ABSTRAK

Penggunaan kenderaan bermotor sebagai media pengangkutan telah menjadi suatu kepentingan dalam kehidupan seharian sehingga pemilikan kenderaan menjadi sesuatu perkara yang biasa, malah mempunyai kenderaan menjadi satu keperluan. Hal ini disebabkan oleh keupayaan kenderaan bagi memendekkan jangka masa yang diperlukan bagi tujuan pengangkutan. Seterusnya menaikkan permintaan bagi kenderaan bermotor secara tidak langsung meningkatkan penggunaan minyak bahan bakar diesel. Walau bagaimanapun, rizab petroleum berkurangan pada kadar yang tinggi setahun demi setahun yang mana mencetuskan satu lagi perlumbaan dalam bidang tenaga bagi menggantikan bahan bakar yang sedia ada dengan bahan bakar alternatif. Biodiesel merupakan salah satu alternatif bahan bakar yang berpotensi tinggi kerana ia dapat memenuhi tujuan sebagai bahan bakar tanpa pembentukan semula secara keseluruhan pada enjin dalaman malahan ia melepaskan bahan pencemar pada kadar yang minimum. Pada kebiasaannya, biodiesel dihasilkan menggunakan teknik esterifikasi ataupun transestrifikasi. Bagi kajian ini, transesterifikasi digunakan dengan cara menghasilkan tindak balas antara methanol dan minyak dedak beras bersama dengan natrium hidroksida sebagai pemangkin. Tiga parameter yang mempunyai lima aras dipilih bagi tujuan transesterifikasi iaitu masa tindak balas, suhu tindak balas dan nisbah molar. Berdasarkan tahap parameter yang telah dipilih, hasil dari eksperimentasi (peratusan biodiesel) dioptimumkan dengan menggunakan Kaedah Tindakbalas Permukaan. Biodiesel yang telah dioptimumkan atau hasil peratusan biodiesel yang tertinggi dikomputasikan oleh perisian statistik 'Minitab 18' dengan menetapkan suhu tindak balas pada 45.5°C, masa tindak balas 68.48 minit dan nisbah molar pada 8.1:1 dalam keadaan berputar pada 400 rpm dan kepekatan pemangkin sebanyak 0.6%. Hasil daripada biodiesel yang dioptimumkan, dicirikan berdasarkan ketumpatannya yang dilaporkan 0.856 SG atau 865 kg/m^3, kelikatan 7.618 cSt, takat awan pada -4.7°C dan titik tuang pada -9.3°C. Sementara itu, hasil peratusan biodiesel bagi biodiesel yang optimum oleh perisian 'Minitab 18' memperolehi nilai peratusan pada 88.11%.

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LIST OF ABBREVIATION

OFAT	One-factor-at-a-time
RSM	Response Surface Methodology
ASTM	American Society for Testing Materials
EN	European Standards
MS	Malaysian Standards
NRBO	Neat Rice Bran oil
RBOB	Rice Bran oil Biodiesel
FAME	Fatty Acid Methyl Ester
SVOs	Straight vegetable oils
MPOB	Malaysia Palm Oil Board
SIRIM	Standards Industrial Research Institute
PME	Palm Methyl Ester
CCD	Composite Central Design
MeOH	Methanol
NaOH	Sodium Hydroxide
DOE	Design of Experiment

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CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter will elaborate on what the project is discussing about, henceforth the Project Background. From the Project Background shall the problem statement, objective of the project and the scope which would be the main focus for the project be developed and comes in order respectively.

1.2 Project Background

Biofuels is basically known for its use which serve as the substitute of what now known in the verge of exhaustion, the diesel fuel. This compound is usually the results of specific types of lipids such as vegetable oil and animal fat on which react chemically towards alcohol to produce fatty acid and glycerol, (Kareem et al, 2016). Since the purpose of developing and researching biofuels is to replace diesel fuel, the characteristics or the fluid properties of the compound would be characterize to bear about the same as the fluid properties of diesel fuel. Biofuels production could be done by using the method of Transesterification or Esterification (Noor et al, 2016).

The process of transesterification is a process on which chemical reaction took place between any kind of lipids assisted with fitting catalyst particular short-chain alcohols such as methanol and ethanol (Stasha and Soh, 2017). According to Kareem et al (2016), the molar ratio for transesterification required at least 3 mole of alcohol and a mole of triglyceride (oil) to yield 3 mole of fatty acid methyl esters (biodiesel) and a mole of glycerol. Meanwhile according to Stasha and Soh (2017), the production of glycerol to

biodiesel ratio is 1:10 as oppose to of 3:1 glycerol to biodiesel ratio suggested by Kareem et al, 2016.

Moreover, a wide range of value-added products could be obtained through the microbial fermentation of crude glycerol. The production of glycerol for all intents and purposes could not be applied exactly for all cases of biodiesel transesterification or esterification production. It really going down on depending towards the oil (variation of lipids) and the catalysts afflicted by variation of transesterification factors. Thus, according to Stasha and Soh (2016), the conventional 'one-factor-at-a-time' (OFAT) approach is less practical because the estimation of the factor effects is inaccurate and point to a vague understanding of the research findings. This issue however, could be avoided by utilizing the optimization of the factors via designing of experiment using Response Surface Methodology (RSM).

RSM is a usually employed with mathematical and statistical techniques for experimental model building. By careful design of experiments, the objective is to optimize certain amount of dependent variables which is influenced by several independent variables. RSM is a tool that could determine the best conditions of the experiment and its required run to produce such results statically. This could be done by assessing the relative significances of numerous independence variables (Stasha and Soh, 2016). Meanwhile according to Ajala et.al, RSM is an effective tool for statistical analysis to find the optimal conditions for different complex process, which able to be applied in the optimization of multiples variable with minimum number of experiments.

Rice wheat oil positions first among the non-regular, cheap, poor quality vegetable oils. In this way, utilization of rice wheat oil as crude material for the creation of biodiesel not only makes the process economical but also generates value added bio-active compounds (Mayank et al, 2016). Rice can be easily collected from the rice husk of the paddy.

About 16 to 20% of crude rice bran oil can be obtained from rice husk. Rice bran oil can be defined as natural oil that is produced extracting from inside of the hull of the paddy It is very difficult to collect the rice bran separately from the hull of the paddy, so most of the cases rice bran oil is extracted from a mixture of rice bran and hull. In the

beginning of rice bran oil production it was mostly used as a cooking oil because it has a higher smoke point (about 232 °C or 450 °F) than the other vegetable oils, which prevent the oil from breaking down to form toxic substances (Ahmed et al, 2014).

1.3 Problem Statement

Petroleum is known to be unrenewable resource since it's a byproduct of fossil fuels and fossil fuels is the deposits of organic matter such as decayed plants and animals that had been exposed to heat and pressure beneath the surface of the Earth for over millions of years ago. To replenish such resources is actually impossible since it takes millions of years to form and the current known reserves are depleting faster than refilling.

Biofuels is basically the alternatives of petroleum due to the fluid properties gain somewhat similar value. According to the data accumulated by Ahmed et al (2014), the fluid properties comparison between Rice Bran Oil Biofuel and fuels correlates somewhat directly, such that the density value obtain for fuel and biofuel are 0.82 and 0.748 (g/cc at 30 degree Celsius) accordingly. The two most commonly use biofuel types are biodiesel and bioethanol which were derived mainly from vegetable oils, seeds and lignocelluloses. Biodiesel can be used to substitute diesel and bioethanol can be used in terms of petrol, (Masjuki and Md Abul, 2013)

In other issue, the biodiesel technology of the present is not sufficient. This is due to the fact that there are array of factor that influence in the quality of producing the biodiesel. In accordance to that, biofuels were used as a blend with fossil-fuels since there are still some distinct value in terms of the fluid properties. It is also described by El-Gald et.al (2014) that the application of biofuels on an industrial scale could not be recommended until it is proved to be economically feasible. Thus come to the conclusion, the purpose of this project is to identify on how to produced biofuels efficiently and yield considerably similar properties to the clarified biofuels standard established by American Society for Testing Materials (ASTM) Organization.

1.4 Objective

The main objectives of this project are:

i. To produce biodiesel by means of transesterification from rice bran oil.
ii. To optimize transesterification factors.
iii. To characterize the biodiesel properties using ASTM D6751 standards.

1.5 Scope of Project

i. Using the transesterification method to produce biodiesel from rice bran oil.
ii. Using Response Surface Method to optimize the biodiesel produced emphasizing on the factor of reaction temperature, reaction time and molar ratio.
iii. Some properties such as density, viscosity, cloud point and pour point were tested and compared to the ASTM D6751 standards.

1.6 The Importance of This Study

As of year 2000, Malaysian government introduced a new fuel policy called the Malaysian Fifth Fuel Policy on which the renewable energy is included as the fifth component in the gas-hydro-coal-fuel oil equation, (Maulud and Hamdani, 2012). Thus, the idea behind this study is not to replace petroleum consumption, but to help create a balanced energy consumption between all of the five components and subsequently reducing the depletion rate of petroleum.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will discuss on the topic of biodiesel progression throughout time and its general information, conjointly with transesterification process and Response Surface Methodology (RSM).

2.2 Biodiesel Development

Biodiesel belongs to one of the types of biofuel. In late 1970s, during the period of energy crisis after world war two, the use of vegetable oils was accepted early despite the initial practicality complication. Following that, Belgian Patent 422877 reported a paper explaining the interchanging of glycerol for ethanol by preparing the ethyl esters of palm oil through a transesterification reaction (Gerhard and Luis, 2016). There are a lot of efforts and method in developing and improvising the properties of vegetable oil (biodiesel fuel) to be approximately to the properties of diesel fuels.

Among the methods developed are pyrolysis. It is a process of thermal decomposition of an organic matters in the absence of oxygen and presence of a catalyst. The substances could be vegetable oils, animal fats, natural fatty acids or methyl esters of fatty acids. According to Atabani et al (2012), the product yielded from pyrolysis of vegetable oil could result in high cetane number, low kinematics viscosity, tolerable amounts of sulfur, water contents and admissible copper corrosion values. Despite that, ash contents, carbon residues, and pour points were unsuitable to be called biodiesel.

Another method as described by Atabani et al (2012), diluting vegetable oils with diesel to reduce the viscosity and improve the performance of the engine does not require any chemical process. However substitution of 100% vegetable oil for diesel fuel is not

practical. Fully using vegetable oils with or without their blends inside engines have been acknowledge to be problematic both short and long terms.

Some other method use solvents such as methanol, ethanol, hexanol, butanol and 1-butanol to produce methanol. For instances, such method is micro-emulsion which could be illustrated as colloidal equilibrium dispersion of optically isotropic fluid microstructure with dimensions generally into 1–150 nm range formed spontaneously from two normally immiscible liquids and one and more ionic or more ionic amphiphiles. According to Atabani et al (2012), biodiesel obtain through this approach yield the maximum viscosity requirement for diesel fuel. Following the results they obtained, it had been explained that short-term performances of both ionic and non-ionic micro-emulsions of aqueous ethanol in soybean oil are nearly as well as that of diesel fuel.

As stated by Atabani et al (2012), transesterification is regarded as the best method among other approaches due to its low cost and simplicity. Transesterification consists of a number of consecutive, reversible reactions. Some fuel properties can be improved through transesterification process such as kinematic viscosity, density, flash point, cetane number and several others shown in the Table 2.1.

Table 2.1: General parameters of the quality of biodiesel

(Source: Atabani et al, 2012)

Parameters	France (general official)	Germany (DIN)	Italy (Uni)	USA (ASTM)
Density at 15°C g/cm³	0.87-0.89	0.875-0.89	0.86-0.90	-
Viscosity at 40 mm²/s	3.5-5.0	3.5-5.0	3.5-5.0	1.9-6.0
Flash Point (°C)	100	110	100	130
Pour Point (°C)	-10	-	0/-5	-
Cetane Number	>49	>49	-	>47
Iodine Number	≤115	≤115	-	-
Ester Content (mass %)	≥96.5	-	≥98	-
Diglyceride (mass %)	≤0.2	≤0.4	≤0.2	-
Triglyceride (mass %)	≤0.2	≤0.4	≤0.1	-
Free glyceride (mass %)	≤0.02	≤0.02	≤0.05	≤0.02
Total glycerol (mass %)	≤0.25	≤0.25	-	≤0.24

2.3 Natural Resources of Biodiesel

There are a total of more than 350 crops containing oil identified as possible feedstock for purpose of biodiesel production. Biodiesels can be produced from straight vegetable oils (SVOs), oils extracted from various plant species and animal fats. Throughout all the option of resources presented, the availability and cost economy are the major factors affecting the large scale production of biodiesel (Salvi and Panwar, 2012). Table 2.2 shows some of the primary biodiesel feedstock use around the global.

Table 2.2: Main feedstock of biodiesel

(Source: Atabani et al, 2012)

Edible Oil	Non-edible Oils	Animal Fats	Other Sources
Soybeans	Jatropha Curcas	Pork lard	Bacteria
Rapeseed	Mahua	Beef tallow	Algae
Safflower	Pongamia	Poultry fat	Microalgae
Rice Bran Oil	Camelia	Fish oil	Tarpenes
Barley	Karanja	Chicken fat	Poplar
Sesame	Cumaru		Switchgrass
Groundnut	Cyanara		Miscanthus
Sorghum	Abutilon		Latexes
Wheat	Neem		Fungi
Corn	Jojoba		

2.3.1 Non-edible Oil

Non-edible oils are the variants of lipids that could not be consumed by human being due to certain factor that could affect direct or indirectly to human health.

In the past decade, more than 95% of the biodiesel is synthesized from edible oil, there are many claims that myriad of complication may arise. By converting edible oils into biodiesel, food provisions are genuinely being converted into automotive fuels. It is believed that immensely colossal-scale production of biodiesel from edible oils may bring global imbalance to the food supply and demand market (Mushtaq et al, 2011).

To overcome this problem, a lot of new ideas and researches have been made to in order to exploit alternative or eco-friendly feedstock such as non-edible oils to produce biodiesel. The non-edible vegetable oils such as *Madhuca Indica, Jatropha Curcas* and