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BIODIESEL PRODUCTION FROM USED FRYING OIL (UFO) USING ALKALINE-BASED CATALYSTS

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This report is submitted as partial requirement for the completion of the Bachelor of Mechanical Engineering (Thermal Fluids) Degree Program

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DECLARATION

"I hereby, declare this report is resulted from my own research except as cited in the references"

Signature : ……………………

Author's Name : ……………………

Date : ……………………

DEDICATION

To my beloved parents

ACKNOWLEDGEMENT

I would like to express my sincere thanks to my "Projek Sarjana Muda (PSM)" supervisor, Puan Mahanum Bt. Mohd. Zamberi, for her guidance and supervision during the study of my project. She is the one who always willing to share her knowledge and ideas without any hesitation. Furthermore, I would also like to thanks to Encik Asjufri B. Muhajir, who is the technician for Combustion Laboratory, had given a lot of guidance when I conducted the experiments in laboratory.

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ABSTRAK

Minyak masak terpakai merupakan sejenis sumber alternatif untuk pengeluaran biodiesel, memandangkan ia dapat mengurangkan kos pengeluaran dengan signifikan. Objektif utama kajian ini adalah untuk mengenal pasti pemangkin alkali yang terbaik untuk pengeluaran biodiesel daripada minyak masak terpakai, dengan kaedah "*alkaline-catalyzed transesterification*". Tindak balas transesterifikasi di antara minyak goreng terpakai dan metanol, dengan kehadiran beberapa pemangkin alkali, akan dijalankan dengan menggunakan proses parameter yang sama. Kesan daripada formulasi pemangkin terhadap penghasilan biodiesel dapat dinilai dengan menggunakan lima pemangkin beralkali yang berlainan (natrium hidroksida (NaOH), kalium hidroksida (KOH), natrium metoksida ($NaOCH_3$), campuran NaOH dengan KOH dan campuran KOH dengan $NaOCH_3$) dalam proses penukaran biodiesel. Satu sampel biodiesel yang dihasilkan daripada minyak tulen dengan pemangkin NaOH, dijadikan sebagai rujukan kepada biodiesel minyak masak terpakai. Pemangkin $NaOCH_3$ telah mencatatkan penghasilan biodiesel daripada minyak masak terpakai yang tertinggi dalam kajian ini, iaitu sebanyak 96.2%. Keputusan telah menunjukan $NaOCH_3$ mempunyai kelebihan dalam faktor penghasilan dan faktor masa. Walaubagaimanupun, kos $NaOCH_3$ yang tinggi telah menjadikan ia tidak sesuai untuk digunakan dalam penghasilan biodiesel yang bertujuan untuk penjualan. Demi keseimbangan dalam faktor penghasilan, faktor masa dan faktor kos, campuran KOH dengan NaOH telah didapati sebagai pemangkin yang paling sesuai untuk penghasilan biodiesel dalam kajian ini.

ABSTRACT

Used frying oil (UFO) is an alternative feedstock for biodiesel production as it can reduce the production cost significantly. The primary aim of this study is to investigate the best alkaline-based catalyst for the UFO biodiesel production, using the alkaline-catalyzed transesterification method. Transesterification reaction of UFO with methanol, in the presence of several alkaline-based catalysts, is carried out under identical typical transesterification process parameters. The effects of catalyst formulation on biodiesel yield are evaluated by using five different alkaline catalysts (sodium hydroxide (NaOH), potassium hydroxide (KOH), sodium methoxide ($NaOCH_3$), mixture of NaOH and KOH, and mixture of KOH and $NaOCH_3$) in the UFO biodiesel conversion process. A sample of virgin oil (VO) biodiesel is produced using NaOH catalyst, as the comparison reference for UFO biodiesel. The highest yield for UFO biodiesel production in this study was achieved by $NaOCH_3$ catalyst, which gave 96.2%. The results of the experiment have shown that the $NaOCH_3$ catalyst had advantages in yields-effective and times-effective for the biodiesel production. However, the cost of $NaOCH_3$ was too high which had made it not practical to use in biodiesel production for commercialize purpose. In order to have a balance between yields-effective, times-effective, and cost-effective characteristics, the mixture of KOH and NaOH catalyst was found to be the optimum catalyst in this biodiesel production study.

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LIST OF SYMBOL

$m_{catalyst}$	=	mass of required catalyst (g)
$m_{titration}$	=	mass of alkaline catalyst (mg) to titrate 1 g of oil into neutral
x	=	mass of oil for one batch of production (g)
$M_{methanol}$	=	molecular weight of methanol (32g/mol)
$V_{titration}$	=	volume of alkaline catalyst using for titration (ml)
C_{alkali}	=	concentration of the alkali solution (mol/liter)
M_{alkal}	=	molecular weight for alkali (mg/mol)
m_{oil}	=	mass of oil used in titration (g)
N_{UFO}	=	mole number of UFO
M_{UFO}	=	molecular weight of UFO (267g/mol)

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CHAPTER 1

INTRODUCTION

1.1 Background

As the one of the major source of energy, petroleum plays an indispensable role in human being development. World petroleum demand is keeps on growing year-by-year since the day it was discovered. However, massive scale of oil use has leading the world to the peak oil production and even some countries are facing the oil depletion circumstances. Consequently, the global oil crisis has driving the world to search for the renewable energy such as wind, sunlight, water, geothermal heat, and biofuel, as an alternative energy.

Among the family of biofuel, biodiesel is the prime candidate as alternative diesel fuels. Biodiesel is commonly produced from vegetable oils or animal fats, through a chemical reaction which is known as transesterification. In transesterification reaction, the oil is reacted with alcohol, in the presence of alkaline catalyst. A great variety of feedstock including palm, soybean, rapeseed, tallow, as well as waste cooking oil can be used as the raw materials in biodiesel production. As an alternative fuel, biodiesel is applicable to use in regular diesel combustion engine, either in pure form or blended with diesel fuel at any concentration. The distinct advantages of biodiesel as diesel fuel are due to its renewability, biodegradability, higher cetane number, and better quality exhaust gas emissions. The standard of biodiesel in U.S is referred to American Society for Testing and Materials (ASTM) standard, while in E.U is referred to EN standard.

There is a huge biodiesel market at United States and European Union. More than 2.7 million tons biodiesel in 2003 was made in Europe, and 8 – 10 million tons is expected in 2010, accounting for 5.75% among the total diesel market, and 20% among the total diesel market in 2020. The capacity of biodiesel production in USA reaches 221,000 tons in 2002, and 1.15 million tons is expected in 2011 and 3.3 million tons in 2016 (Meng, X.M *et al.* 2008). In fact, Malaysia has the potential to be major biodiesel producer in the world, since it is currently the world's number two producer of palm oil. Determination of Government of Malaysia (GOM) in further develop palm biofuel industry could be seen by the implementation of Biofuel Industry Act 2007, Investment Tax Allowance (ITA) for biodiesel projects, and establishment of Malaysia Palm Oil Board (MPOB). However, due to the violent swing of palm oil prices and retail petroleum prices are subsidized in Malaysia, the biodiesel becomes less competitive and development of biodiesel industry in Malaysia becomes slow. Currently, there are only 12 biodiesel plants in operation in Malaysia and another four plants are still in construction (Hoh, R., 2009)

The most critical challenge encountered by biodiesel is the biodiesel price is still higher than retail diesel fuel. The cost of biodiesel production varies depending on the base stock, geographic area, variability in crop production from season to season, the price of crude petroleum, and other factors (Demirbas, A. 2008). Thus, most the current biodiesel researches are prefer to use the used frying oil (UFO) in biodiesel production, as the price of these waste lipids is much lower than other virgin oils. A huge amount of used frying oil (UFO) generated by the restaurants, fast food outlets, and food processing industries everyday and everywhere around the world. Instead of let the used frying oil becomes a disposal burden to government, it is actually can be recycled to be an alternative raw material in biodiesel production. However, large amount of free fatty acids in UFO is undesirable in alkali catalyzed transesterification reaction, and so, the conversion of UFO to biodiesel becomes more complicated. Consequently, further study is necessary to find out the most appropriate parameters (UFO) for used frying oil transesterification reaction process.

1.2 Objective

The overall aim of this study is to find out the best catalyst for the used frying oil (UFO) biodiesel production. Within this broader goal, there are three specific objectives:

1) To study the biodiesel production model, process criticality and constrains parameters.

2) To produce the biodiesel by using current existing lab-scale experimental apparatus.

3) To produce the used frying oil (UFO) and virgin oil (VO) biodiesel using several alkaline-base catalysts.

1.3 Scope

From the objectives, the study is narrowed down to become more specific, in order to give a clearer view on the critical points. The scopes including in this study are:

1) To summarize the current build of transesterification reactor, inclusive of its process criticality, constrain parameters and raw material used of each model in order to develop comprehensive overview of biodiesel production related-matter.

2) From the comprehensive overview, this study is extend to producing biodiesel by using the lab-scale experimental apparatus and designing process parameters inclusive raw material mixing ratio, catalyst

concentration, reaction temperature, and so on by consider the cost-effective factor and meets the minimum oil required for dyno-engine testing.

3) To establish the yield matrix of UFO biodiesel for each catalyst used during the biodiesel production. The matrix will inclusive of VO biodiesel using common catalyst, sodium hydroxide (NaOH) as a reference for comparison.

1.4 Problems of Statement

Problems of statement are used to show the relationship between the current issues in biodiesel production and this study. The objectives and scopes of this study are designed to cope with those issues in biodiesel production. The problems of statement of this study are:

1) Numerous of biodiesel production models have been designed and build for biodiesel study. A standardized model with an optimized set of process parameters is prerequisite in order to obtain the optimum productivity of biodiesel.

2) The design and setup of a commercial biodiesel plant is a complicated, costly, and massive work. The construction of small capacity biodiesel production model is always essential in optimizing the process parameters and learning the biodiesel production related-matter.

3) Catalyst formulation is one of the critical process parameters in biodiesel production. Variation of catalyst can be used in catalyzed the transesterification reaction, and each of them would give the unique effects on biodiesel yield and characteristics.

CHAPTER 2

LITERATURE REVIEW

Chemically, biodiesel is defined as a mixture of mono alkyl esters of long chain fatty acids that commonly derived from vegetable oils or animal fats. The major reason that vegetable oils and animal fats are transesterified to alkyl esters (biodiesel) is that the kinematic of the biodiesel is much closer to that of diesel fuel (Knothe, G. 2005). Direct use of vegetable oils in diesel engine is considered to be not satisfactory and impractical as its high viscosity will normally leads to operational problems in diesel engine such as filter clog, formation of deposits, poor fuel injection and reduce the lifespan of the engine. Thus, the main purpose of transesterification reaction is to reduce the viscosity of the vegetable oils and animal fats to the acceptable level for engine use.

Numerous of study on conversion of vegetable oils and animal fats into biodiesel has been conducted over past several years. The developed methods in making biodiesel are such as alkali catalyzed transesterification, direct acid catalyzed transesterification, conversion of oil into its fatty acids and then into biodiesel, and non-catalytic transesterification.

2.1 Theory of Biodiesel Production

Nowadays, several of contemporary biodiesel production technologies have been developed. From manual to advance, different biodiesel production processes are providing distinct specifications in capacity, cost, feedstock type, process flow, and production scale. Each of them owns particular preferences and limitations in biodiesel production, and so, comprehensive considerations vitally important in the selection of primary biodiesel production process.

Biodiesel may be produced either in small or large quantities, depending on it is for personal use or commercial intent. In general, biodiesel production process can be placed into two broad categories, which is batch processing and continuous processing. In batch processing, the reactants are added into the reactor in a pre-determined amount. Chemical reactions between the reactants are carried out within the reactor, under the desired reaction conditions. The complete reacted chemical content is then move to consequent processes. The biodiesel is produced batch by batch through this system, and the characteristics of biodiesel may vary between the batches.

In contrast, continuous processing involves a steady flow of reactants into reactor, constant products out from the reactor after reaction. The biodiesel product has more uniform characteristics under this system. Batch processing system is commonly use in the biodiesel production with smaller scale, while continuous processing system is preferable for larger production capacity. Most of the current biodiesel studies are using batch processing for their biodiesel production, as it is suitable in handling production with variable feedstock qualities.

2.2 Biodiesel Production Model

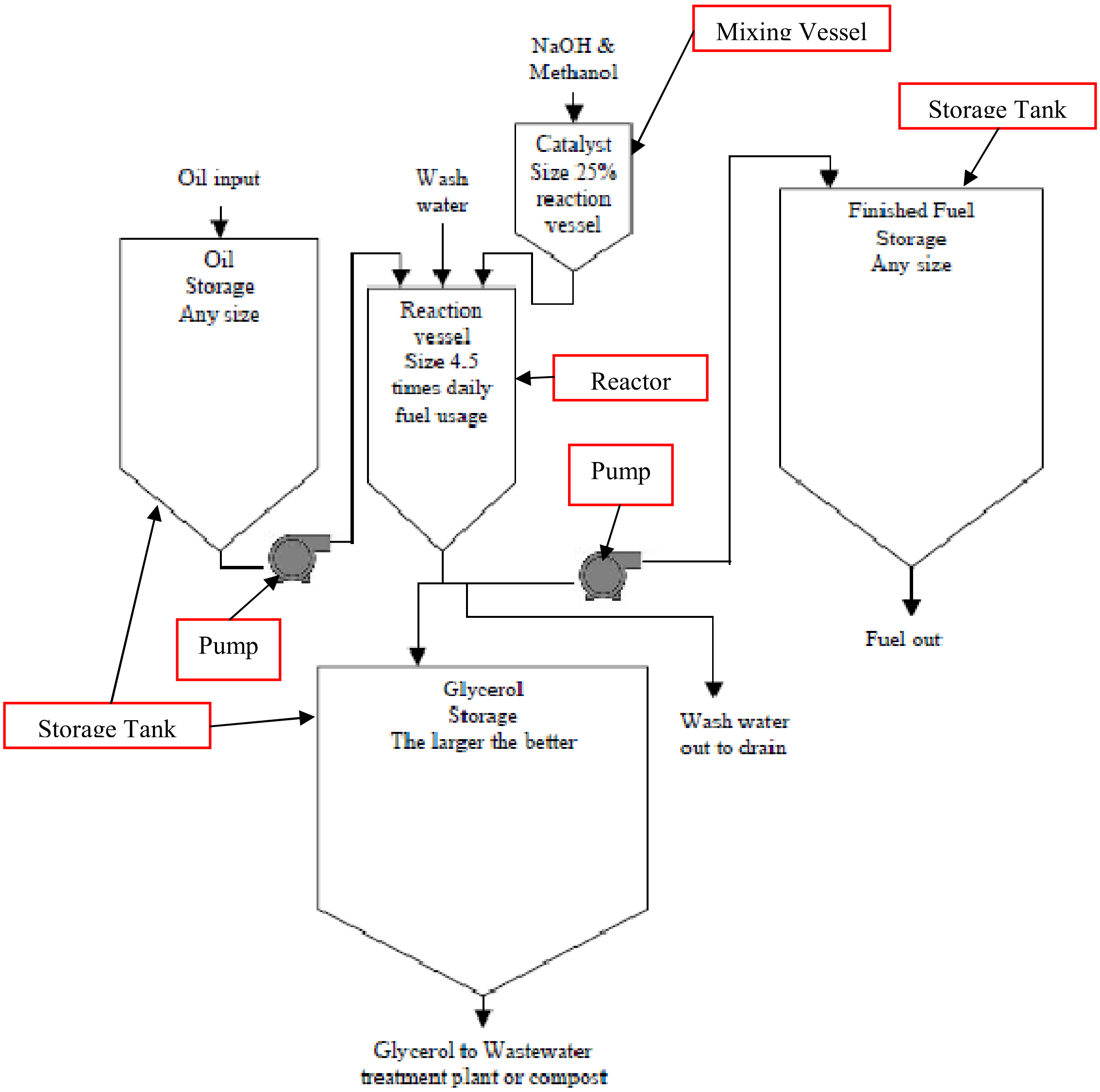

Figure 1: Biodiesel Production Model

A simple and complete biodiesel production layout is shown in the Figure 1. In general, the primary biodiesel production equipments are including reactor, mixing vessel, pumps, stirrer, heating elements and storage tanks.

The purchased feedstock is normally store in the oil storage tank. The sizing of the storage tank is depending on the amount of oil that requires supplying to the reactor in each cycle of production. A small mixing vessel is normally necessary in a biodiesel production, for the purpose to pre-mix the required amount of alcohol and catalyst solution before the mixture reacts with the oil in reactor. Based on the Figure 1, the location of the alcohol-catalyst mixing vessel has to be higher than the reactor, for the purpose to avoid mixture in the reactor to flow into the mixing vessel.

Reactor or reaction vessel is the most vital component in a biodiesel plant. It is the place where oil and pre-mixing alcohol-catalyst solution will undergo the transesterification reaction, in order to produce the biodiesel. Reactors can be divided into two major types, which are batch reactor and continuous reactor, depending on the production system of the biodiesel plant. The sizing of the reactor is depending on the required biodiesel capacity for each cycle of production.

Heating and stirring system is normally integrated to the reactor, as the transesterification reaction is needed to be maintained in certain range of temperature and mixing degree, in order to have the optimum biodiesel yield. Heating elements and stirrer also used in washing and drying process, for remove the water content and increase the mixing degree in biodiesel.

The byproduct of biodiesel conversion is glycerol. It is normally drained out from the reactor after the phase separation process has completed. It will be store in its storage tank before going to water treatment plant or further refined processes. Pump is used in direct the distilled water into the reactor to wash the biodiesel, after the glycerol has drained out. In order to increase the purity of the biodiesel, it is commonly let the biodiesel to undergo few cycle of washing process.

Finished fuel storage tank is used to keep the biodiesel, which is ready to be used. The fuel storage tank can be in any size, as long as it is capable to store the maximum amount of yield for every cycle of production.

2.3 Biodiesel Production Processes

Though there are several methods in making biodiesel, but alkali catalyzed transesterification method still hold the most favor approach in biodiesel production. The reason that makes it preferable is high biodiesel yield is able to obtain, relative to low temperature, pressure, and simple reactions during the process. The overall biodiesel production process using alkali catalyzed transesterification method can be divided into four major stages: raw materials preparation, transesterification, washing, and drying.

2.3.1 Raw Material Preparation

The biodiesel production process begins with the pretreatment for the raw materials, as the quality of feedstock brings significant effects on the biodiesel yield. Virgin oil is the oil extracted from crops using solely mechanical or other physical means in conditions, particularly thermal condition, which do not alter the oil in anyway. Since the virgin oil has no undergo any treatment, it has the better properties than tallow or used frying oil. Virgin oil can be directly use in transesterification reaction.

The conversion of used frying oils to biodiesel is more complicated compare to the virgin oils. Used frying oils contain higher amount of free fatty acids (FFA), water content, and food particles. Those contents are undesirable in transesterification process as FFA would react with alkali catalyst to form soap, and high water content would drive the triglycerides to form free fatty acids. Consequently, pretreatment of used frying oils is necessary to filter out the solid particles, and reducing the acid values and water contamination in the oil.

Titration is the common laboratory technique that used to determine acid number of the feedstock. The acid number represents the degree of free fatty acids in the oil. In alkali catalyzed transesterification, free fatty acids will consume certain