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"I hereby declare that I have read this thesis and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluids) with Honours"

Signature: …………………………………

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BIODIESEL PRODUCTION FROM WASTE VEGETABLES OIL USING CATALYZED TRANSESTERIFICATION

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature:	…………………………………
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Date:	………………………………….

DEDICATION

Special to my beloved parents

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With the name Allah swt that Most Beneficent and the Most Merciful………

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ABSTRAK

Objektif utama kajian ini adalah untuk mencari parameter yang paling optima didalam proses penghasilan biodiesel dimana ianya melibatkan pengawalan nisbah molar, suhu tindak balas, masa tindak balas, dan kepekatan pemangkin. Kaedah yang digunakan yang digunakan didalam kajian ini adalah melalui kaedah transesterifikasi dimana ianya termasuk proses pra-pemprosesan, transesterifikasi, basuhan, dan pengeringan. Keseluruhan proses penghasilan biodiesel telah dijalankan pada skala makmal dengan menggunakan minyak masak terpakai, metanol, dan kalium hiroksida (KOH). Eksperimen telah dijalankan dengan mengawal parameter yang telah dipilih seperti berikut : 0.5 wt. % dan 0.9 wt. % daripada KOH, 30 minit dan 60 minit reaksi masa, 4:1 dan 6:1 nisbah molar metanol kepada minyak, dan 60°C suhu tindak balas. Jumlah penghasilan biodiesel yang tertinggi telah dicapai dibawah parameter optima iaitu pada 60°C suhu tindak balas, 60 minit masa tindak balas, 0.5 wt. % KOH kepekatan pemangkin, dan 4:1 nisbah molar. Dibawah parameter optima, jumlah penghasilan biodiesel yang paling tinggi telah dicapai pada 95.52%. Keputusan telah menunjukkan bahawa pengurangan nisbah molar dari 4:1 kepada 6:1 dan kepekatan pemangkin dari 6:1 kepada 4:1 telah menghasilkan nilai kecekapan yang tinggi. Nilai penghasilan biodiesel didalam eksperimen berbeza-beza dari 82.5% kepada 95.52%.

ABSTRACT

The main objective of this study is to find the the optimum conditions for the biodiesel production where it involved the control parameter of molar ratio, reaction temperature, reaction time and catalyst concentration. Biodiesel production methods that used in this study is via transesterification which includes pre-processing process, transesterification, washing and drying process. All of the biodiesel production is carried out in the laboratory scale by using waste vegetables oil (WVO), methanol and potassium hydroxide (KOH). The experiment were conducted of control parameter selected as follows : 0.5 wt.% and 0.9 wt.% of KOH, 30 and 60 minutes of reaction temperature, 4:1 and 6: 1 molar ratio methanol to oil, and 60 °C of reaction temperature. The highest yield was achieved under optimum condition at 60 °C of reaction temperature, 60 minutes reaction time, 0.5 wt.% of catalyst concentration, and 4:1 molar ratio. Under the optimum condition, the highest yield percentage was reached at 95.52%. The result was noted that the reduction of molar ratio from 6:1 to 4:1 and catalyst concentration from 0.9 wt.% to 0.5 wt.% produced the higher value of coversion efficiency (yield). Futhermore, the yield percentage of the experiment was varied from 82.5% to 95.52%.

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$M_{methanol}$	=	Molecular Weight of Methanol (32g/mol)
x	=	Mass of Oil for one Batch of Production
N_{WFO}	=	Mole Number of WFO
M_{WFO}	=	Molecular Weight of WFO (267 g/mol)
$m_{catalyst}$	=	Mass of Catalyst (g)
$V_{titration}$	=	Volume of titration (ml)
$M_{methanol}$	=	Molecular weight methanol (g/mol)
$N_{methanol}$	=	Molar ratio of methanol
m_{oil}	=	Mass of WVO per 1 ml
$m_{titration}$	=	Mass of alkaline catalyst (mg) to titrate 1 g of oil into neutral
$C_{alkaline}$	=	Concentration of alkaline solution in 1000 ml
WVO	=	Waste vegetables oil
VO	=	Virgin oil
KOH	=	Catalyst of potassium hydroxide
NaOH	=	Sodium Hydroxide
^{o}C	=	Degree Celsius

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Fossil fuels depletion, environmental pollution and energy crisis has increased world intention on the renewable and green technology. The application of fossil fuels enhances the production of toxic gas and the greenhouse effect which are the major contributor to the worst environment (Prafulla, D. P. et al., 2009). Moreover, the increases of global population and rapid industrial development have led to an increase of the energy demand every year. Consequently, green technology has been introduced in order to reduce dependence on fossil resources and promote the production of energy from renewable energy resources such as wind, solar, tidal, wave, biomass, geothermal and biofuel. By using the renewable energy resources in produce the energy, the energy crisis can be avoided, while the lifespan of the fossil fuel able to extended.

Industrial revolution that was experienced in Europe at the end of the 18^{th} century and early 19^{th} century has led the energy become important for economic development and daily life. Consequently, the globe has seen energy consumption demand was increased dramatically when entering the 20^{th} century due to the rapid pace of the automotive industry, airplanes, and the generation of electricity in daily life. This situation made the coal and fossil fuel become important in producing the energy for the global mankind. Even though the producing of the energy from the renewable energy resources was founded, the fossil fuel remains the major contributors in support the global energy demand. Based on Energy Information Administration (EIC) it has shown that until 2010, petroleum, natural gas, and coal contributes to 83% of world energy production. In Malaysia, around 95% of the energy production was generated by the petroleum, natural gas and coal for industrial usage and other propose. Moreover, Malaysia dependency on the fossil fuel was expected to continue until 2030.

Chemically, biodiesel is a long chain of the alkyl esters which is produced either from animal fats or vegetable oils. Biodiesel can be used directly on the engine and machine without any modification due to the kinematic properties of biodiesel similar to the diesel fuel. Besides that, the biodiesel fuel is a renewable resource, easily degradable by bacteria, environmentally friendly, reduces the release of toxic gas, and does not produce black smoke (Keera, S.T. et al., 2011). However, before it is being used in any application, the production of the biodiesel must meet few standards requirements such as ASTM D 6751 and ASTM D 975.

In Malaysia, the biodiesel fuel are not widely used due to the cost of biodiesel production is still higher than the retail price of oil. In the biodiesel production, the using of the virgin oil (VO) as the raw materials will increase the cost of the production. In order to reduce the cost of biodiesel production, the waste vegetable oils as the raw materials have been identified as the most suitable method in decreasing the production cost of biodiesel. Furthermore, the Waste Vegetables oil (WVO) was easily available in this country since it is widely used in food industries. However, the WVO usually have the high content of the Free Fatty Acid (FFA), where it will give significant affection yield of the biodiesel production. Therefore, the content of the FFA in WVO need to reduce before it being use in the biodiesel production.

Ahouissoussi, N. B. C. et al., (1998), was pointed out that in biodiesel production, the raw materials are the primary element that will determine the cost of a biodiesel production. Apart from the cost, the amount of raw material resources in the certain country also will determine the type of feedstock that can be applied in the biodiesel production. For example, in the United States and European country, the soy and rapeseed oil have become main raw material in the biodiesel production due to the a huge sources in both countries. While, countries in Southeast Asia for example Malaysia and Indonesia prefer to use palm oil as a main raw material in biodiesel production whereas ethanol which was produced from sugar cane has been widely used in Brazil for long time as one of the renewable fuels. At the moment, the United States has taken a drastic step on the algae research in order to make the algae become main raw materials in the biodiesel production as the preparation to fulfill the fuel demand in the future. At the beginning, around USD 2 billion were invested in this project. Algae were preferred because it is easy to breed and handled compared to other sources of biodiesel production.

The biodiesel production process can be done by using transesterification process. This process involves a mixture of raw materials and alcohol with catalyst as the assistance of reaction process where it produces the biodiesel and glycerin (Zamberi, M. M. et. al., 2010). Several parameters as reaction time, reaction temperature, molar ratio and weight of the catalyst must be considered in order to obtain a quality biodiesel in term of yield production percentage.

1.2 OBJECTIVE

In this research, the objective of the study is divided into several specific points:

i. To produce biodiesel of B5, B10, B20 and B100.
ii. To find the optimum condition of reaction time, molar ratio, catalyst concentration, and cost per batch of biodiesel production.
iii. To study the biodiesel production model.

1.3 SCOPE

The scope of the research is used to show the limitation of the study and give the clearest view of the research. The specific scopes of this study were:

i. This research is extends to produce the biodiesel fuel by lab scale apparatus via transesterification method. By comprehensive overview, the biodiesel production is carried out with controlling the parameter selected inclusive molar ratio methanol to oil, reaction temperature, reaction time and catalyst concentration.

ii. To establish the best yield percentage of biodiesel fuel, the WVO is used as raw material, methanol as alcohol and KOH as primary catalyst. Furthermore, this study only producing the biodiesel blends of B5, B10, and B20 by mixture of the best yield of biodiesel fuel with pure diesel fuel.

1.4 PROBLEM STATEMENT

Problem statements are used to show the relationship between 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:

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

ii. The cost of biodiesel production always being the essential circumstances in produce the biodiesel fuel, the high cost of feedstock will leads the increases production cost of biodiesel fuel. The used of WVO as the raw materials and methanol as the alcohol able to decrease the cost of biodiesel production significantly.

iii. The optimum condition in producing the biodiesel fuel always being the critical variables that should take seriously. In this study, the experiments have been conducted by transesterification method with variation of experimental parameter such as molar ratio, reaction temperature, reaction time and catalyst concentration. Each of the parameter condition would give the unique effects on the biodiesel yield and characteristic.

CHAPTER 2

LITERATURE REVIEW

2.1 BIODIESEL

Biodiesel is the most potential resource in replacing the dependence on fossil fuels in the future since it is renewable and has the similar characteristics of diesel fuel. According to the Piyanuch, N. et al., (2010), scientifically biodiesel is a mixture of mono-alkyl esters of long chain free fatty acid (FFA) and also known as fatty acid methyl esters (FAME). In the research by Ayhan, D. et al., (2009) stated that the superiority of the biodiesel fuel is liquid nature-portability, already available, renewability, higher heat content, lower sulfur content and biodegradability. Apart from that, biodiesel fuel also presents the high viscosity, weak volatility, and reactivity of unsaturated hydrocarbon chain. In the production of biodiesel, the greatest resistance that needs to overcome is the high viscosities of vegetable oil where the viscosity must be reduce before being used in the engine system. Based on Fangrui, M. et al., (1999), there are four methods that can be used to produce the biodiesel fuel which was known as blending, micro emulsions, thermal cracking and transesterification method. All of these methods able to reduce the viscosity of biodiesel as well as to obtain a high yield of biodiesel.

However, transesterification process is the famous method that applied in the production of the biodiesel. In 2012, Diya'uddeen, B, H. et al., was mentioned that the process of transesterification only suitable to use for the process which involve the vegetables oil as the feedstock. In the transesterification process, there are three main element involved which are vegetables oil, alcohol and catalyst. The biodiesel productions by transesterification process able to apply even though in small scale of biodiesel production. In addition, there are two (2) types of vegetable oil which are edible and non-edible oil. The edible oil narrowly related with the food source, while the non-edible oil not interrelated with the food source. Besides that, the used of the edible oil might affect to the food resources to the people, whereas the used non-edible oil may use largely land and it consists of some toxic in that oil. Furthermore, the uses types of vegetable oil depend on the most abundant resources in the countries.

2.2 BIODIESEL PROPERTIES

The usage of fuel in the engine system should be able to meet the standard prescribed before run in engine to ensure the engine operate properly and prevent the damage on the engine component. As the biodiesel is the vise potential in replace the dependent of fossil fuel in the future, biodiesel must able to fulfill the entire standard required. According to Hoekman, S. K. et al., (2012), the chemical and physical properties of biodiesel fuel varies according to the raw materials used in biodiesel production. In addition, there are varieties of raw materials that can be used to produce biodiesel fuel where all of them has different characteristic. Moreover, the variation type of the biodiesel production will lead to the differences of chemical and physical properties of biodiesel fuel.

Therefore, many studies were attempted to ensure that biodiesel could fully replace diesel oil in the future. Normally, the properties of biodiesel fuel is determined by comparing it with the pure diesel fuel which includes the amount of carbon, hydrogen, oxygen, specific gravity, fuel cetane number, viscosity, and basic mass. Nevertheless, the cetane number is most important properties that must be obtain by the biodiesel because cetane number level show how close the biodiesel fuel to the fossil fuel characteristic. For the Fatty Acid Methyl Ester (FAME), the important characteristic that must be consider are viscosity, cetane number, specific gravity, flash point, iodine value, and heating value. In addition, ASTM standard has stated that the B100 biodiesel must meet the ASTM D6751 standard before being used in any engine system. The information includes in Table 2.1 shows the method and parameters required for the biodiesel production it measured by ASTM and EN standards.

Table 2.1: ASTM standard properties of B100
(Standard specification of ASTM, 2008).

Property	Biodiesel blend stock (B100)			
	U.S. (ASTM D6751-08)		Europe (EN 14214)	
	Limits	Method	Limits	Method
Water and sediment (vol. %, max)	0.05	D 2709	0.05	EN 12937
Total contamination (mg/kg, max.)	-	-	24.00	EN 12662
Kinematic viscosity @ 40 $^oC(mm^2/s)$	1.9-6.0	D 445	3.50-5.00	EN 3104/ 3105
Flash point, closed up (^{o}C, min)	93	D 93	101.00	EN 3679
Methanol (wt. %, max.)	0.20	EN 14110	0.20	EN 14110
Cetane no. (min)	47	D 613	51.00	EN 5165
Cloud point (^{o}C)	Report	D 2500	Country specific	-
Sulfated ash (wt. %, max)	0.020	D 874	0.02	EN 3987
Total ash (wt. %, max.)	-	-	-	-
Gp I metals Na+K (mg/kg, max.)	5.0	EN 14538	5.00	EN 14108/ 14109

Gp II Metals Ca+Mg (mg/kg, max.)	5.0	EN 14538	5.00	EN 14538
Total Sulfur (ppm, max.)	15	D 5453	10.00	EN 20846
Phosphorous (ppm, max.)	10	D 4951	4.00	EN 14107
Acid no. (mg KOH/g, max)	0.50	D 664	0.50	EN 14104
Carbon residue (wt.%, max)	0.05	D 4530	0.30	EN 10370
Free glycerin (wt. %, max.)	0.02	D 6584	0.02	EN 14105/ 14106
Total glycerin (wt. %, max)	0.24	D 6584	0.25	EN 14105
Mono glyceride (wt. %, max)	_	_	0.80	EN 14105
Diglyceride (wt. %, max)	_	_	0.20	EN 14105
Triglyceride (wt. %, max)	_	_	0.20	EN 14105
Distillation (T_{90} ^oC, max)	36	D 1160	-	-
Copper strip corrosion (3-h at 50 ^oC, max)	N0. 3	D 130	No.1	EN 2160
Oxidation stability (h @110 ^oC)	3.0	EN 14112	6.00	EN 14112
Linoleic acid methyl ester (wt. %, max)	_	_	12.00	EN 14103
Polyunsaturated acid methyl ester (wt. %, max)	_	_	1.00	EN 15799
Ester content (wt. %, max)	_	_	96.50	EN 14103