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TO DETERMINE ALKALINE CATALYST FOR THE JATROPHA OIL BIODIESEL PRODUCTION

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DEDICATION

Special dedication to my mum and family members that always love me,
my supervisor, my beloved friends, my fellow colleague,
and all faculty members

For all your love, care, support, and believe in me

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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"

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Authors: ....
Date: ....

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ABSTRACT

Jatropha curcas oil is an alternative feedstock for biodiesel production as it has more advantages than other crops. The aim of this study is to determine the best alkaline catalyst for the production of *Jatropha* biodiesel. In this study, *Jatropha curcas* oil was used as feedstock for biodiesel production through process of alkali-catalyzed *transesterification*. The *transesterification* reaction with sodium hydroxide (NaOH) and potassium hydroxide (KOH) as catalyst was used to investigate the optimum conditions and to study the effects of variables on the reaction. These variables included methanol to oil ratios, catalyst concentration, cost effectiveness, reaction temperatures and reaction times. The parameter used in this study are methanol to oil ratio of 6:1, a catalyst concentration of 1.0% w/w of oil, a reaction temperature of 60°C and a reaction time of 40 minutes. NaOH catalyst has recorded production of biodiesel from *Jatropha curcas* by 71.1% for sodium hydroxide (NaOH) and 70.1% for potassium hydroxide (KOH). The results also shows that NaOH had advantages in cost effectiveness and amout of catalyst used. *Jatropha* biodiesel then need to undergo a few test to determine their fuel characteristic such as kinematics viscosity, and density. The test of *Jatropha* biodiesel shows kinematics viscosity of biodiesel with NaOH is 4.34 mm^2/s while 4.31 mm^2/s for biodiesel with KOH. The density for biodiesel with NaOH is 0.87 kg/l and for biodiesel with KOH is 0.89 kg/l. All the values were accepted for both kinematics viscosity and density.

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ABSTRAK

Minyak *Jatropha curcas* merupakan bahan mentah alternatif untuk pengeluaran biodiesel kerana ia mempunyai banyak kelebihan berbanding tanaman lain. Tujuan kajian ini adalah untuk menyiasat pemangkin alkali terbaik untuk penghasilan biodiesel *Jatropha*. Dalam kajian ini, minyak mentah *Jatropha curcas* telah digunakan sebagai bahan mentah bagi pengeluaran biodiesel "alkaline-catalyzed *transesterification*". Tindak balas *transesterification* dengan pemangkin alkali iaitu natrium hidroksida (NaOH) dan kalium hidroksida (KOH) telah digunakan bagi menyiasat keadaan optimum dan untuk mengkaji kesan pembolehubah terhadap tindak balas. Pembolehubah ini termasuklah nisbah metanol kepada minyak, kepekatan pemangkin, keberkesanan kos, suhu tindak balas dan masa tindak balas. Parameter yang digunakan dalam kajian ini adalah nisbah methanol kepada minyak 6:1, kepekatan pemangkin 1.0% w/w minyak, suhu tindak balas 60°C, dan masa tindak balas 40 minit. Pemangkin NaOH telah mencatatkan penghasilan biodiesel daripada minyak *Jatropha Curcas* sebanyak 71.1% dan 70.1% untuk kalium hidroksida (KOH). Keputusan juga menunjukkan NaOH mempunyai kelebihan dalm faktor kos dan jumlah pemangkin yang diperlukan. *Jatropha* biodiesel kemudian perlu menjalani ujian beberapa untuk menentukan ciri-ciri bahan api mereka seperti kelikatan kinematik, dan ketumpatan. Ujian Jatropha biodiesel menunjukkan kelikatan kinematik bagi biodiesel dengan NaOH adalah 4.34 mm^2/s manakala 4.31 mm^2/s bagi biodiesel dengan KOH. Ketumpatan bagi biodiesel dengan NaOH adalah 0.87 kg/l dan biodiesel dengan KOH ialah 0.89 kg/l. Semua nilai ujian kelikatan kinematik dan ketumpatan adalah dalam skala dan diterima.

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LIST OF SYMBOL

$V_{Titration}$ = Volume of alkaline using titration (ml)

$C_{Alkaline}$ = Concentration of alkaline solution (mol/liter)

$M_{Alkaline}$= Molecular weight for alkaline (mg/mol)

m_{Oil} = Mass of oil used in titration (g)

X = Mass of oil for one batch production.

M_{CJCO} =Molecular weight of Jatropha oil

N_{CJCO} = Mole number of jatropha oil

$M_{Methanol}$=Molecular weight of Methanol

v = Kinematic viscosity, mm^2/s

C = Calibration constant of the viscosity, $(mm^2/s)/s$

t = Mean flow time, s

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CHAPTER 1

INTRODUCTION

1.1 Background

Biodiesel have a great promise as an energy that could be locally produced and used. It is easy to make as it is from vegetables oil or animal fats. Biodiesel is an alternative fuel that is relatively safe and easy to process when carefully approached. It also can be used in any diesel engine without any modifications. Chemically, biodiesel is defined as mono alkyl esters of long chain fatty acids derived from vegetables oil or animal fats. Biodiesel is non-toxic and biodegradable that produces about 60% less net carbon dioxide emission than petroleum based diesel.

Since biodiesel can be used in conventional engine without modification, this renewable fuel can directly replace petroleum products. An overall 92% reduction in toxic emissions compared to diesel, biodiesel is by far the best alternative fuel option at present. It is also the only alternative fuel currently available that has an overall positive life cycle energy balance. Biodiesel now, is sustainable, renewable, and domestically produced.

Biodiesel also have a by-product that is glycerin, which can be easily used to make soap and candle or other product. Other than *Jatropha curcas* oil, biodiesel can also be produced from other biologically derived oils such as soybean oil, corn oil, palm

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oil, coconut oil, waste cooking oil, peanut oil, sunflower oil, rapeseed oil, pork lard, beef tallow, as well as other types of animal fats.

In this research, biodiesel is produced through the reaction of the *Jatropha Curcas* oil with methanol in the presence of a catalyst to yield glycerin and biodiesel (chemically called methyl esters). The most common way to produce biodiesel is by *transesterification* process and the common catalyst used is alkaline catalysts such as Potassium Hydroxide and Sodium Hydroxide as the cost of these catalysts are cheaper and the process can achieve high purity and yield of biodiesel product in a short time.

1.2 Problem Statement

Biodiesel has become one of the important alternative fuels that can replace diesel because of the limited sources of petroleum and the environmental concerns from exhaust gases if using petroleum diesel as fuel. Biodiesel is made from renewable resource that contains the simple alkyl esters of fatty acids. The production of biodiesel can be reduced by using less expensive feedstock such as inedible oils, animal fats, waste food oil and by products of the refining vegetables oils (Berchmans, H. J. and Hirata, S. 2008).

Biodiesel is usually produced from vegetable oil that is highly used as food consumption by humans. And the prices of this vegetable oil have increases due to the high consumption. Therefore, biodiesel from non edible oil are found to be a potential feedstock for biodiesel. So, ways and means have been sought for many years to be able to produce oil-substitute fuel to replace diesel fuel.

In this study, *Jatropha Curcas L* oil was selected as raw material for production of biodiesel because of the price that is cheaper compare to diesel fuel and vegetable oil. And it can grow in tropical and subtropical climates around the world (Berchmans, H. J. and Hirata, S. 2008).

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In Malaysia, there are a few places that do the planting of *Jatropha* tree and the closest is in Klebang, Melaka. However, there are problems with the usage of *Jatropha Curcas L* oil which are the higher viscosity than diesel fuel, lower volatilities that causes the formation of deposits in engine due to incomplete combustion and incorrect vaporization characteristics.

The most common way to reduce the viscosity is by *transesterification*, which refers to a catalyzed chemical reaction involving vegetable oil and an alcohol to yield fatty acid alkyl esters (biodiesel) and glycerol (Sastry S.V.A.R. and Ramachandra 2012).Methanol is the most commonly used alcohol because of its low cost and the catalyst used can be varied from acid, alkali or lipase. Only well refined vegetable oil with less than 0.5% free fatty acid (FFA) can be used as raw material for this alkali *transesterification* process (Wang, Y. *et al.* 2006). The alkali process proven faster and the reaction conditions are moderated (Razali, N. *et al*. 2010).

For this research, the optimal parameters that need to be investigated is (alcohol to oil ratio, cost effectiveness, temperature, reaction time and concentration of catalyst) to produce high yield of biodiesel production.

1.3 Objectives

1. To produce biodiesel from *Jatropha Curcas Linnaeus* oil using alkali catalyst which are sodium hydroxide (NaOH) and potassium hydroxide (KOH).
2. To determine the suitable alkali catalyst in producing biodiesel from *Jatropha Curcas Linnaeus* with respect to its alcohol to oil ratio, cost effectiveness, reaction temperature, reaction time and concentration of catalyst.

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1.4 Scope

1. This research is to study about biodiesel production and understanding the process in producing the biodiesel.
2. Determine the optimum conditions for production of biodiesel with suitable alkali catalyst.
3. To evaluate the parameter used in this research for both catalyst used.

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CHAPTER 2

LITERATURE REVIEW

2.1 Biodiesel

Biodiesel is defined as mono alkyl esters of fatty acids derived from vegetable oil or animal fat such as used oils from the frying industry, soybean oil, rapeseed oil, tallow, rubber seed oil and palm oil (Rashid, U. *et al*. 2010). The word "*Bio*" represents as a renewable and biological source in contrast to traditional petroleum-based diesel fuel while "diesel" refers to its use in diesel engines. As an alternative fuel, biodiesel can be used in neat form or mixed with petroleum-based diesel. The production of biodiesel must meet the standard for biodiesel ASTM D6751 before can be used by any engine.

2.1.1 ASTM Standard

The parameters for B100 biodiesel are specified by biodiesel standard, ASTM D6751 as shown in Table 2.1. This standard identifies the parameter that pure biodiesel (B100) must meet before being used as a pure fuel or blended with petroleum based Diesel.

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Table 2.1: ASTM D6751 Biodiesel (B100) Specification
(Source: National Renewable Energy Laboratory, Biodiesel Handling and Use Guide, Fourth Edition, NREL/TP-540-43672, January 2009.)

Property	ASTM Method	Limits	Units
Calcium and Magnesium, combined	EN 14538	5 max.	ppm
Flash Point	D93	93.0	Degrees C
Alcohol Control (one of the following must be met)			
1. Methanol Content	EN 14110	0.2 max	% mass
2. Flash Point	D93	130 min	Degrees C
Water & Sediment	D2709	0.050 max	% vol
Kinematic Viscosity, 40°C	D445	1.9 - 6.0	mm^2/sec
Sulfated Ash	D874	0.020 max	% mass
Sulfur S15 Grade	D5453	0.0015 max	% mass (ppm)
Sulfur S500 Grade	D5453	0.05 max	% mass (ppm)
Copper Strip Corrosion	D130	No. 3 max	
Cetane Number	D613	47 min	
Cloud Point	D2500	Report to customer	Degrees C
Carbon Residue 100% sample[a]	D4530	0.050 max	% mass
Acid Number	D664	0.50 max	mg KOH/gm
Free Glycerin	D6584	0.020 max	% mass
Total Glycerin	D6584	0.240 max	% mass
Phosphorus Content	D 4951	0.001 max	% mass
Distillation, T90 AET	D 1160	360 max	Degrees C
Sodium/Potassium, combined	EN 14538	5 max	ppm
Oxidation Stability	EN 14112	3 min	hours
Cold Soak Filterability	Annex to D6751	360 max	seconds
For use in temperatures below -12 C	Annex to D6751	200 max	seconds

Table 2.2: Comparison of certain key parameters for B100 biodiesel versus conventional petroleum-based diesel fuel

Fuel properties	**Diesel**	**Biodiesel**	**units**
Fuel standard	ASTM D957	AS6751	Btu/gal
Lower heating value	129050	11170	Mm^2/s
Kinematics viscosity at 40°C	1.2-4.1	1.9-6.0	
Specific gravity at 60°C	0.85	0.88	Kg/l
Calorific Value	50	175	MJ/kg
Density	7.079	7.328	lb/gal

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At present, fossil fuels are the main resources of energy. The fossil-based resources, such as gasoline, petro-diesel and natural gas are limited and insufficient for world's future energy demands. Thus, there is much concern for search of renewable fuels. With the introduction of biodiesel as a renewable energy, many researches about biodiesel have been conducted around the world. From the previous research, there are many advantages by using biodiesel as a new energy.

The advantages of biodiesel are as follow:-

1. The used of biodiesel will not affect the environment in negative way. The smoke from vehicles running on biodiesel fuel will release smoke without any harmful substances and the environment clean without any pollutants.
2. Biodiesel is cheap compared to the prices of petroleum are going hike year by year.
3. Biodiesel can be used without any modification to engine.
4. Biodiesel can be produce from many feedstock's such as soybeans, palm oil, rapeseeds, and some other byproducts.
5. The feedstock's for biodiesel is easily to provide as it comes from crops.

The disadvantages of biodiesel are as follow:-

1. The great quantity of biodiesel will have to use in order to meet the energy level from the petroleum oils. The energy level for biodiesel is less than energy from petroleum oils.
2. The prices for crops will increase as production of biodiesel will required many of these crops.
3. To produce biodiesel, a lot of energy is required from crops and energy from sowing, fertilizing and harvesting.
4. Biodiesel has an ability to clean dirt from the filter and can get clogged if the biodiesel is used in the engine that has been using petroleum for a long time.

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2.2 *Jatropha Curcas*

Jatropha curcas is a species of flowering plant in the spurge family called *Euphorbianceae*, that native to American and tropics such as Mexico and central America. But, it is cultivated in tropical and subtropical regions around the world and become natural in some areas as it is easy to grow in any soil.

Jatropha curcas Linnaeus, a multipurpose plant, contains high amount of oil in its seeds which can be converted to biodiesel has gained lot of importance for the production of biodiesel. The sustainability and availability of sufficient of less expensive feedstock from vegetables oil, particularly *Jatropha curcas* and the efficient of processing technology to produce biodiesel will be crucial determinants of delivering a competitive biodiesel (Parawira, W. 2010). From the others 26 type of fatty acid from vegetables oil, *Jatropha curcas* are the most suitable for biodiesel production (Mohibbe, AM. *et al.* 2005). Table 2.3 shows the physical properties of *Jatropha curcas*. *Jatropha Curcas* is very remarkable as a substitute for diesel. If *Jatropha curcas* is planted in large scale, it has the potential to create a new agricultural industry to provide low cost biodiesel feed stock.

In Malaysia, Bionas Malaysia is a company that promotes *Jatropha Curcas* planting for fuel production, job, and wealth creation within Malaysian economy. Figure 2.1 shows the overall plant of Jatropha curcas that consists of fruit, flower, seed and cut fruit. The fatty acids composition of the Malaysian *J. curcas* oil is rich in oleic and linoleic acids and the oil can be classified as unsaturated oil. Hence the Malaysian *Jatropha curcas* oil has a great potential for oleochemical application such as surface coating and low pour point biodiesel. Therefore, it is convivial to have more research on *Jatropha curcas* seed oil in the future to explore its potentials for future industrial oilseeds crop. Table 2.4 shows the chemical properties of *Jatropha Curcas* and Table 2.5 shows the composition of fatty acid in *Jatropha Curcas* seeds.

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(a) (b) (c) (d)

Figure 2.1: Fruit(a), flower(b), seed(c), and cut fruit(d)

(Source: BDF Malaysia Sdn. Bhd)

Table 2.3: Physical properties of Jatropha Curcas

(Source: Hamball et al (2006), * Valtllngom and Liennard (1997) in Gubitz et al,1997)

Property	Unit	Value
Flashpoint	°C	236
Density (15°C)	g/cm3	0.9177
Viscosity (30°C)	nm2/s	49.15
Carbon residue	%(m/m)	0.34
Ash / sulfuric acid	%(m/m)	0.007
Pour point	°C	-2.5
Water content	ppm	935
Sulfur content	ppm	<1
Cetane number*		39
Calorific value*	MJ/kg	39.35

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Table 2.4: Chemical properties of *Jatropha Curcas*

(Source: Anthony, S. et al., 2011)

Item	**Value**
Acid Value	38.2
Saponification Value	195.0
Iodine Value	101.7
Viscosity at 31^{o}C	40.4
Density	0.92

Table 2.5: Fatty Acid Composition
(Source: Anthony, S. et al., 2011)

Palmitic Acid(%)	4.2
Stearic Acid(%)	6.9
Oliec Acid(%)	43.1
Linoleic Acid(%)	34.3
Other Acid(%)	1.4

2.2.1 Advantages and Disadvantages of *Jatropha Curcas*

There are number of crops that can be used as feedstock for biodiesel production. Thus, the question arise why should we use *Jatropha Curcas* instead of other crops. *Jatropha* have more advantages compare to other crops.

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The following factors made *Jatropha* as an advantage to use as shown below:

1. *Jatropha* is easy to cultivate and can grow on all climatic conditions and soils. It can live well in tropical climates such Malaysia.
2. As it is easy to cultivate *Jatropha* in Malaysia, the cost production of *Jatropha* biodiesel is less expensive because the feedstock is in Malaysia.
3. *Jatropha* proved to have higher yield output than other crops.
4. It is easy to maintain the *Jatropha* plant as it is drought resistance, has the ability to grow well on poor or infertility soil, and need only little amount of water.
5. Use low maintenance because there is no need to use pesticides or other polluting substances.
6. *Jatropha* plant can lives and can be harvested more than 45 years

The disadvantages of *Jatropha*:-

1. The leaves and seeds are toxic to human beings and animals
2. The use of soil to cultivate *Jatropha* could become an issue
3. The price is not distorted by competing food uses as the *Jatropha Curcas* nut and Oil are inedible.
4. Could have potential gender conflicts.
5. Other than biodiesel, *Jatropha* also could also be used to make soap.

2.3 Biodiesel Production Process

Biodiesel production is the process of synthesizing biodiesel. Biodiesel is a liquid fuel source that has same characteristics with petroleum based diesel. The most common method for production of biodiesel is by reacting the triglyceride which is vegetables oil or animal fats with a short chain alcohol such as methanol or ethanol which this reaction known as *transesterification*. Figure 2.2 shows the model of biodiesel production.

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