# THE DEVELOPMENT OF HOME MADE APPARATUS FOR THE PRODUCTION OF BIODIESEL FROM NEW COOKING OIL

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**A report submitted in fulfillment of the requirement for the award of the Degree of Bachelor of Chemical Engineering**

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## DECLARATION

‘I declare that thesis is the result of my own research except as cited references. The thesis has not been accepted for any degree and is concurrently submitted in candidature of any degree.”

| | |
|---|---|
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| Date | : 27 November 2006 |

# DEDICATION

*Special Dedicated o my…*

*Beloved parent;*
*Hj.Zainal Abidin b. Hj. Salleh*
*Hjh. Normah bt. Ibrahim*

*My family members*

*In memory;*
*Angah, 1979 - 2006*

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# ABSTRACT

Due to the increase in the price of the petroleum and the environmental concerns about pollution coming from car gases, biodiesel is becoming a developing area of high concern. Biodiesel is the name of a clean burning alternative fuel, produced from domestic, renewable resources. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in compression ignition (diesel) engines with little or no modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. Developing of biodiesel is not so hard process. There are different ways of production, with different kinds of raw materials, such as crude oil, new cooking oil or frying cooking oils. In this project, the new cooking oil will be used to produce biodiesel. Biodiesel is made through a chemical process called transesterification whereby the glycerin is separated from the fat or vegetable oil. The process leaves behind two products, that is methyl esters (biodiesel) and glycerin, a valuable by product usually sold to be used in soaps and other products. Before biodiesel can be produce, there is some circumstance to face. One of the problems is the apparatus. During this time, there are no small scale biodiesel have been developed. The main objective of this project is to develop a home made apparatus for biodiesel production. After the apparatus have been made, five test batch will be held with each batch is different from it's Methanol quantity, to determine the best ratio of Methanol to oil used to get high yield of biodiesel. The last step in this thesis is analyzing the result using Gas Chromatography. The first observation showed that the best ratio Methanol to oil is 4:1. But, GC result showed that all five samples contain high of methyl palmitate that is major component of biodiesel. So, it can conclude that the product that comes from this apparatus is biodiesel.

# ABSTRAK

Dengan peningkatan harga bahan api serta timbulnya kesedaran terhadap pencemaran alam sekitar yang datangnya dari pelepasan asap kenderaan, biodiesel menjadi pemangkin untuk mengatasi masalah ini. Biodiesel bermaksud bahan api alternatif yang diperolehi dari alam sekitar dan boleh diperbaharui. Biodiesel tidak mengandungi petroleum, tetapi ia boleh dicampur dengan diesel petroleum untuk membentuk campuran biodiesel. Ia boleh digunakan sebagai bahan bakar bagi enjin diesel, tanpa memerlukan pengubahsuaian terhadap enjin. Biodiesel mudah digunakan, selain ia mesra alam, tidak bertoksik dan mempunyai kandungan sulfur yang rendah. Terdapat beberapa bahan mentah yang boleh digunakan untuk menghasilkan Biodiesel, seperti minyak sawit mentah, minyak masak baru dan minyak masak yang telah digunakan. Dalam kajian projek ini, minyak masak baru telah digunakan untuk tujuan penghasilan biodiesel. Biodiesel terhasil melalui proses transesterifikasi di mana glyserin dipisahkan daripada lemak sayuran. Proses ini meninggalkan dua hasil, iaitu biodiesel dan hasil sampingan, glycerol, yang digunakan untuk membuat sabun. Tetapi, beberapa masalah telah ditemui ketika membuat biodiesel ini. Salah satu masalahnya adalah alatannya. Kini, masih tiada alat untuk menghasilkan biodiesel dalam kuantiti yang kecil. Objektif utama kajian ini adalah untuk membina alat untuk menghasilkan biodiesel. Selepas alat ini dibina, lima ujian telah dijalankan dengan setiap satunya dibezakan dengan kuantiti methanol, untuk mengetahui nisbah terbaik methanol kepada minyak untuk mendapat hasil biodiesel tertinggi. Langkah terakhir ialah menganalisa menggunakan GC. Hasil pemerhatian awal, didapati nisbah terbaik methanol kepada minyak adalah 4:1. Tetapi, keputusan GC menunjukkan semua sampel mengandungi methyl palmitate, iaitu kandungan tertinggi dalam biodiesel. Kesimpulannya, alat yang dibina ini mampu menghasilkan biodiesel.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Overview of Research

Biodiesel, an easy-to-make, clean burning diesel alternative made from vegetable oil or fats, has great promise as an energy industry that could be locally-produced, used, and controlled.

Biodiesel is an alternative fuel that is relatively safe and easy to process when conscientiously approached. Biodiesel is made from vegetable oil or animal fat that can be used in any diesel engine without any modifications.

Chemically, it is defined as the mono alkyl esters of long chain fatty acids derived from renewable lipid sources. Biodiesel is typically produced through the reaction of a vegetable oil or animal fat with methanol in the presence of a catalyst to yield glycerin and biodiesel (chemically called methyl esters).

Boasting an overall 92% reduction in toxic emissions compared to diesel, Biodiesel is by far the best alternative fuel option at present. Biodiesel is the only alternative fuel currently available that has an overall positive life cycle energy balance. It is renewable, sustainable, and domestically produced.

The only by-product of this form of Biodiesel is glycerin, which can be easily used to make soap or other products.

Biodiesel can also be produced from other biologically derived oils such as soybean oil, canola oil, sunflower oil, hemp oil, coconut oil, peanut oil, palm oil, corn oil, mustard oil, flaxseed oil, new or waste cooking oil, rapeseed oil, cottonseed oil, beef tallow, pork lard, as well as other types of animal fat.

Biodiesel is actually as old as the diesel engine itself. Rudolf Diesel, the 19th-century originator of diesel technology, used refined peanut oil to run his invention. Diesel's workhorse engine took off, but the rise of cheap crude oil killed his vision of farmers growing their own fuel.

## 1.2 Problem Statement

Biodiesel is needed for Malaysia future, toward the vision 2020. Since it's made domestically, it reduces country's dependence on foreign oil. Using Biodiesel keeps fuel buying dollars at home instead of sending it to foreign countries. This reduces Malaysia trade deficit and creates jobs. It's sustainable & non-toxic. We have face the fact that this country going to run out of oil eventually. Biodiesel is 100% renewable because it will never run out, besides it is nearly carbon-neutral, meaning it contributes almost zero emissions to global warming. Biodiesel also dramatically reduces other emissions fairly dramatically. According to previous research, it reduces engine wear by as much as one half, primarily because it provides excellent lubricity.

## 1.3 Research Objective & Scope

The main objective in this thesis is to develop a home made Biodiesel apparatus.

The scopes of this thesis are as follows:-

i. To develop a home made Biodiesel apparatus.
ii. To determine appropriate ratio of methanol to oil to get high amount of biodiesel
iii. To analyze the product from all sample.

## 1.4 Research Contribution

After finish doing this research, it is hope that biodiesel will get from the home made Biodiesel apparatus. The successful of this apparatus will bring the yield of the Biodiesel.

As the acknowledgement, world fossil fuel will finish in a few years. So, it is very important to develop a Biodiesel apparatus or processor. At the end, Biodiesel will be the major and most use fuel for the future because it's special characteristic and environment friendly.

From this research, it widen our knowledge about biodiesel apparatus, as an alternative to assist users to make their own biodiesel at home.

## 1.5 Thesis Layout

Basically, chapter 1 will cover all about introduction. Here, some basic review about the biodiesel apparatus and knowledge about biodiesel will be reveal. The second chapter will go further about the thesis, and it will be called literature review. Some review that has been published will be study again. The third chapter will be go into method, to do this research study. The fourth chapter will be going deep into these research, because there will be result and discussion. All the data will put into this chapter, and will be discuss. The last chapter, that is chapter five is the conclusion, from this research.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Biodiesel Description

Due to the increase in the world petroleum price every day and the environmental concerns about pollution coming from the vehicle gases, Biodiesel is becoming a developing area of high concern research.

Biodiesel is an alternative fuel for diesel engines that is produced by chemically reacting a vegetable oil or animal fat with an alcohol such as methanol. The reaction needs a strong base as reaction catalyst, such as sodium or potassium hydroxide, and produces new chemical compounds called methyl esters. And the methyl ester is refer to Biodiesel it self.

‘‘Bio’’represents its renewable and biological source in contrast to traditional petroleum-based diesel fuel; ‘‘diesel’’refers to its use in diesel engines [1]. As an alternative fuel, Biodiesel can be used in neat form or mixed with petroleum-based diesel. The mix Biodiesel in nowadays market can be B5, which represent 5% Biodiesel, B20 for 20% and B100 for 100% Biodiesel mixture with petroleum diesel.

Biodiesel derived from a renewable, domestic resource, thereby relieving reliance on petroleum fuel imports. It is biodegradable and proven less toxic than ordinary diesel fuel. Compared to petroleum-based diesel, Biodiesel has a more positive

combustion emission profile, such as low emissions of carbon monoxide, particulate matter and unburned harmful hydrocarbons, such as Carbon Monoxide. Carbon dioxide produced by combustion of Biodiesel can be recycled naturally by photosynthesis, which can lower the impact of Biodiesel combustion on the greenhouse effect [2]. Biodiesel has a relatively high flash point (150 ºC), which makes it less volatile and safer to transport or handle than petroleum diesel [3]. It provides lubricating properties that can reduce engine wear and extend engine life [4]. In brief, these merits of Biodiesel make it the best alternative to petroleum based fuel and have led to its use in many developing countries, especially in environmentally sensitive areas.

Vegetable oils, especially palm oil have become more attractive research recently because of their environmental benefits and the fact that it is made from renewable resources. More than 100 years ago, Rudolph Diesel tested vegetable oil as the fuel for his engine [5]. Palm oils have the great potential for substitution of the petroleum distillates and petroleum based petrochemicals in the future. Others vegetable oil fuels are not now petroleum competitive fuels because they are more expensive than petroleum fuels [6]. However, with the recent increases in petroleum prices and the uncertainties concerning petroleum availability, there is renewed interest in using vegetable oils in Diesel engines. The Diesel boiling range material is of particular interest because it has been shown to reduce particulate emissions significantly relative to petroleum Diesel [7]. There are more than 350 oil bearing crops identified, among which only Palm oil, sunflower, safflower, soybean, cottonseed, rapeseed and peanut oils are considered as potential alternative fuels for Diesel engines [8]. The emergence of transesterification can be dated back as early as 1846 when Rochieder described glycerol preparation through ethanolysis of castor oil [9]. Since that time, alcoholysis has been studied in many parts of the world. Also, methyl esters have been prepared from palm oil by transesterification using methanol in the presence of a catalyst (KOH) in a batch reactor [10].

## 2.2 Transesterification

Transesterification is not a new process. The best way to make a fine biodiesel that can reduce broken to engine's vehicle is transesterification process. Many researchers around the world agree that is Biodiesel that make from transesterification process, does not need to modify diesel engine before using the Biodiesel. The scientists Duffy and Patrick conducted it as early as 1853 [11]. Transesterification involves the reaction between an alcohol and a vegetable oil or animal fat that are mixtures of triglyceride (esters of glycerin with long chain fatty acids).

For more understanding about the chemical reaction, the Biodiesel past through a process known as transesterification, as shown in the figure below,

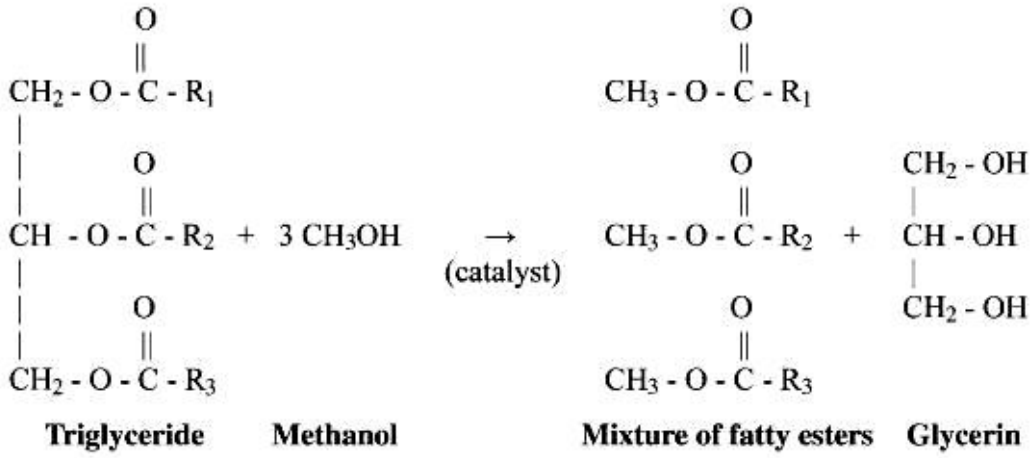


**Figure 2.1:** Transesterification Process [1].

where R1, R2, and R3 are long hydrocarbon chains, named free fatty acid chains.
There are only five chains that are most common in palm oil and animal fats (others are

present in small amounts) [12]. Although the research did not anticipate the production of alkyl esters for fuel, most of the processes for Biodiesel production were developed in the early 1940s. The glycerol has a much higher density so it is easily removed by settling or centrifuge. The glycerol-free methyl esters were then reacted with alkali to form soap.

Methanol is the most commonly used alcohol because of its low cost and is the alcohol of choice in the processes developed in this study. Among the alcohols that can be used in the transesterification reaction are methanol, ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are used most frequently. Ethanol is a preferred alcohol in the transesterification process compared to methanol because it is derived from agricultural products and is renewable and biologically less objectionable in the environment, however methanol is used because of its low cost and its physical and chemical advantages (polar and shortest chain alcohol).

In general, a large excess of methanol is used to shift the equilibrium far to the right, so the reaction will not go back to be Triglyceride anymore. That is one reason why methanol is need as catalyst in this reaction. Transesterification reactions can be alkali-catalyzed, acid-catalyzed or enzyme-catalyzed. As for the enzyme-catalyzed system, it requires a much longer reaction time than the other two systems [13]. To date it has only been carried out on the laboratory scale and therefore will not be further discussed here in. Chemically, transesterification (also called alcoholysis) means taking a triglyceride molecule or a complex fatty acid, neutralizing the free fatty acids, removing the glycerin and creating an alcohol ester. A catalyst is usually used to improve the reaction rate and yield. Alcohols are primary or secondary monohydric aliphatic alcohols having 1–8 carbon atoms [14].

The the transesterification reaction can be catalyzed by alkalis, acids or enzymes. Several alcoholysis catalysts, known to be effective for reactions between simple alcohols and soybean oil, were evaluated and found to be ineffective toward alcoholysis

of ethylene glycol with soybean oil under traditional reaction conditions. An initial survey of alternative catalysts revealed that organometallic tin complexes were effective but unsatisfactory due to their toxicity and the difficulty in recovering the catalyst. Satisfactory performance for several alcoholysis reactions was achieved with calcium carbonate catalysts even though at higher temperatures, typically greater than 475 K [15].

## 2.3 Catalyzed System

The transesterification process is catalyzed by acids, preferably by sulfonic and sulfuric acids. These catalysts give very high yields in alkyl esters, but the reactions are slow, compare to acid catalyzed. The vegetable oil molar ratio is one of the main factors that influence the transesterification process. An excess of alcohol favors the formation of the products. But, an excessive amount of alcohol makes the recovery of the glycerol difficult, so that the ideal vegetable oil ratio has to be established empirically, considering each individual process. The protonation of the carbonyl group of the ester leads to the carbocation which, after a nucleophilic attack of the alcohol, produces the tetrahedral intermediate, which eliminates glycerol to form the new ester, and to regenerate the catalyst hydro carbon. According to this mechanism, carboxylic acids can be formed by reaction of the carbocation with water present in the reaction mixture and acid-catalyzed transesterification should be carried out in the absence of water [17]. Tungstated zirconia– alumina, which is the example of alkali catalyzed is a promising catalyst for the production of Biodiesel fuels because of its activity for the transesterification as well as the esterification [18]

The alkali-catalyzed transesterification of vegetable oils proceeds faster than the acid-catalyzed reaction. The first step is the reaction of the base with the alcohol, producing an alkoxide and the protonated catalyst. The nucleophilic attack of the alkoxide at the carbonyl group of the triglyceride generates a tetrahedral intermediate,

from which the alkyl ester and the corresponding anion of the diglyceride are formed. The latter deprotonates the catalyst can react with a second molecule of alcohol and starts another catalytic cycle. Diglycerides and monoglycerides are converted by the same mechanism to a mixture of alkyl esters and glycerol. Alkaline metal alkoxides (CH3ONa) are the most active catalysts, since they give very high yields (98%) in short reaction times (30 min) even if they are applied at low molar concentrations (0.5 mol%). The presence of water gives rise to hydrolysis of some of the produced ester, with consequent soap formation. Potassium carbonate, used in a concentration of 2 or 3 mol% gives high yields of fatty acid alkyl esters and reduces the soap formation [19].

## 2.4 Fuel Characterization

The Biodiesel usually or can characterized by determining its density, viscosity, higher heating value (HHV), cetane index, cloud and pour points, characteristics of distillation and flash and combustion points according to ISO norms [20]. The fuels are characterized by evaluation of the parameters required in ASTM, or American Standard Test Materials.

Determination of physical and chemical properties using standard test methods

| Property | Symbol | Standard method | Unit |
|---|---|---|---|
| Density | d | ASTM D4052-91 | g/ml |
| Iodine value | IV | AOCS CD1-25 1993 | cg I/g oil |
| Saponification value | SV | AOCS CD3 1993 | mg KOH/g oil |
| Higher heating value | HHV | ASTM D2015-85 | MJ/kg |
| Cloud point | CP | ASTM D2500-91 | K |
| Pour point | PP | ASTM D97-93 | K |
| Flash point | FP | ASTM D93-94 | K |
| Cetane number | CN | ASTM D613 | – |
| Kinematic viscosity | KV | ASTM D445 | $mm^2/s$ at 311 K |
| Sulfur content | SC | ASTM D5453-93 | wt.% |
| Carbon residue | CR | ASTM D 524 | wt.% |
| Ash content | AC | ASTM D482-91 | wt.% |

**Figure 2.2:** Physical and chemical properties of Biodiesel [16]

The Biodiesel esters were characterized for their physical and fuel properties, as shown in the table above. Methyl and ethyl esters prepared from a particular vegetable oil had similar kinematics viscosities, cloud points and pour points, whereas methyl, ethyl, 2-propyl and butyl esters derived from a particular vegetable oil had similar gross heating values. However, their densities, which were 2–7% higher than those of Diesel fuels, statistically decreased in the order of methyl similar to 2-propyl > ethyl > butyl esters [21]. The viscosities of Biodiesel fuels are twice compare to petroleum diesel. The cloud and pour points of petroleum diesel are significantly lower than those of the Biodiesel fuels. The Biodiesel fuels produced slightly lower power and torque and higher fuel consumption than petroleum diesel. Biodiesel is an efficient, clean, 100% natural energy alternative to petroleum fuels. Among the many advantages of biodiesel fuel are the following: safe for use in all conventional Diesel engines, gives the same performance and engine durability as petroleum Diesel fuel, non-flammable and non-toxic, reduces tailpipe emissions, visible smoke and noxious fumes and odors.

## 2.5 Biodiesel Economy

Biodiesel has become more attractive recently because of its environmental benefits. The cost of biodiesel, however, is the main obstacle to commercialization of the product. With cooking oils used as raw material, the viability of a continuous transesterification process and recovery of high quality glycerol as a biodiesel by-product are primary options to be considered to lower the cost of biodiesel [22]. Most of the biodiesel that is currently made uses soybean oil, methanol and an alkaline catalyst. The high value of soybean oil as a food product makes production of a cost effective fuel very challenging. However there are many other vegetable source, despite soybean that could be converted to biodiesel. Using new cooking oil is just another alternative to make biodiesel. The problem with processing these low cost oils and fats is that they often contain large amounts of FFA that cannot be converted to biodiesel using an alkaline catalyst [23].

## 2.6 Methanol as Part of the Process

The use of Methanol, also known as ‘wood alcohol’, is commonly used in BD production for its reactivity.

Generally, it is easier to find than ethanol. Sustainable methods of methanol production are currently not economically viable. Transesterification is the process of using an alcohol e.g. methanol, ethanol, propanol or butanol), in the presence of a catalyst to chemically break the molecule of the raw renewable oil into methyl or ethyl esters of the renewable oil with glycerol as a by-product [6].

Methanol is the commonly used alcohol in this process, due in part to its low cost. However, ethanol is a preferred alcohol in the transesterification process compared to methanol because it is derived from agricultural products and is renewable and biologically less objectionable in the environment. Alkali catalyzed transesterification has been most frequently used industrially, mainly due to its fast reaction rate.

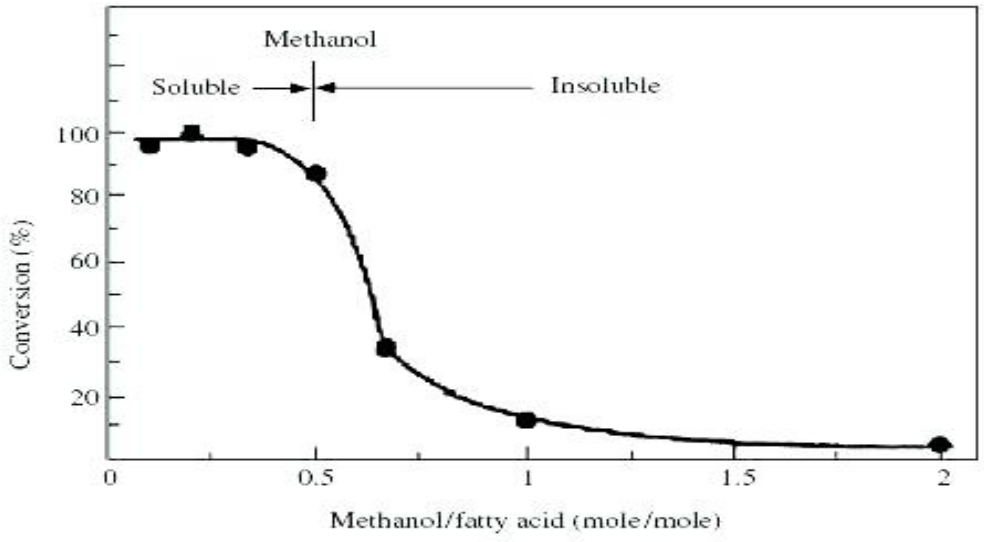


**Figure 2.3:** Methanolysis of vegetable oil [21]

The perfect mixture of methanol to perform a quality Biodiesel is 1.6 times the theoretical amount of an alcohol, such as methanol, which contained 0.1 to 0.5% sodium or potassium hydroxide, to an oil or fat. When performed at 80 8C, this process provided 98% conversion to alkyl esters and high-quality glycerol. These patents contain the following observations about the transesterification process:

- Excess alcohol of more than 1.6 times the stoichiometric amount is required for complete reaction.

- The amount of alcohol used can be reduced by conducting the reaction in steps, where part of the alcohol and catalyst are added at the start of each step, and the glycerol is removed at the end of each step.

- Besides methanol, other alcohols can be used including ethanol, propanol, isopropanol, butanol, and pentanol.

- Water and free fatty acids inhibit the reaction. Higher alcohols are particularly sensitive to water contamination.

## 2.7 Development of Home Made Biodiesel Apparatus

The simple answer why home made Biodiesel apparatus is build is because of it use for diesel engine. New cooking oil is chosen because it have high contain of triglycerides, that can be made for Biodiesel. The main component in palm oil, that is palmitic, olenic and olein combines, in the name of triglycerides. Besides that, making Biodiesel from new cooking oil is much less in cost of production, compare to raw palm oil.