

EXPERIMENTAL ANALYSIS ON BIODIESEL PRODUCTION FROM WASTE  
COOKING OIL USING CONVENTIONAL METHOD

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of the requirements for the award of the degree in  
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### **SUPERVISOR DECLARATION**

“I hereby declare that I have read this thesis and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluid)”

Signature: .....

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*Dedicated to my beloved Mother and Father*

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Firstly, I want to express my heartfelt gratitude to my mother Mrs. Amson and the rest of my family members who gave me continuous support in whatever I do. I would like to thank my supervisor, Puan Nur Fathiah Binti Mohd Nor for her valuable advice and assistances towards completing this work. I would also like to thank to all my friend, Utem staffs and technicians who directly or indirectly helped me in completing this Final Year Project.

## ABSTRACT

As the price of crude oil increases day by day, many people are switching to biodiesel in order to save money and decrease the dependence on fossil fuels. In the current market, biofuels are expensive to produce and the investment put into this industry is fairly low. Usage of waste products such as Waste Cooking Oil as the raw feedstock and cockle as catalyst would reduce the production cost, hence increase the production of biodiesel. This study is focused on producing biodiesel with highest yield percentage via Transesterification of Waste Cooking Oil using calcined cockle as catalyst at various Methanol to Oil Ratio, Catalyst Weight Percentage, Reaction Time and Reaction Temperature of 60 °C to 64 °C. The study showed that methanol to oil ratio and catalyst weight percentage directly affects the yield percentages with the effects of methanol to oil ratio slightly higher compared to effect of catalyst weight percentage. At Methanol to Oil ratio of 15:1, 12% catalyst weight percentage and 2 hour of reaction time with reaction temperature of 60 °C to 64 °C a high percentage of yield was produced at 94.4%. The end product biodiesel was tested for few selected properties and the result obtained showed that the values of the tests are within the allowed range of ASTM D 6751, making it as an acceptable B 100 biodiesel.

## ABSTRAK

Oleh kerana harga minyak mentah meningkat dari hari ke hari, ramai orang beralih kepada biodiesel untuk menjimatkan wang dan kurang bergantung kepada bahan api fosil. Dalam pasaran semasa, minyak biodiesel adalah mahal untuk dihasilkan dan pelaburan yang dibuat dalam industri ini agak rendah. Penggunaan bahan buangan seperti Sisa Minyak Masak sebagai bahan mentah dan kerang sebagai pemangkin dapat mengurangkan kos pengeluaran, lalu meningkatkan proses penghasilan biodiesel. Kajian ini memberi tumpuan kepada penghasilan biodiesel dengan peratusan tertinggi melalui transesterifikasi Sisa Minyak Masak menggunakan kerang yang dikapur sebagai pemangkin dengan jumlah Metanol Nisbah Minyak, Peratus Berat Pemangkin, Reaksi Masa berbeza dan Suhu Reaksi daripada 60 °C kepada 64 °C. Kajian ini menunjukkan bahawa metanol nisbah minyak dan peratusan berat pemangkin secara langsung memberi kesan kepada peratusan hasil biodiesel dengan kesan metanol nisbah minyak lebih tinggi berbanding dengan kesan peratusan berat pemangkin. Pada Methanol nisbah Minyak 15: 1, 12% peratusan berat pemangkin dan 2 jam masa tindak balas dengan suhu tindak balas 60 °C kepada 64 °C, peratusan hasil yang tinggi dihasilkan dengan hasilnya 94.4%. Produk terakhir biodiesel telah diuji untuk beberapa sifat-sifat kimia terpilih dan keputusan yang diperolehi menunjukkan bahawa nilai ujian adalah dalam julat yang dibenarkan ASTM D 6751, menjadikan minyak ini boleh diterima sebagai biodiesel B 100.

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**LIST OF SYMBOLS**

|               |   |                |
|---------------|---|----------------|
| $\rho_{oil}$  | = | Oil density    |
| $\rho_{h_2o}$ | = | Water density  |
| $N$           | = | Normality      |
| $g$           | = | Gram           |
| $^{\circ}C$   | = | Degree Celsius |
| $cm$          | = | Centimeter     |
| $mm$          | = | Millimeter     |
| $m$           | = | Meter          |
| $s$           | = | seconds        |
| $K$           | = | Kelvin         |

## LIST OF ABBREVIATIONS

|      |   |   |
|------|---|---|
| WCO  | = | Waste Cooking Oil                         |
| ASTM | = | American Society of Testing and Materials |
| KOH  | = | Potassium Hydroxide                       |
| CaO  | = | Calcium Oxide                             |

## CHAPTER 1

### INTRODUCTION

#### 1.1 BACKGROUND OF STUDY

Rudolf Diesel invented the diesel engine in 1892 with a significantly differing mechanism when compared to the standard gas engine. In comparison through context, a standard gas engine uses the process of combustion by igniting vaporised fuel in a cylinder and a spark plug. Whereas diesel engines compresses air in a cylinder heating it to a temperature which causes it to combust on contact with the fuel. The fuel to energy conversion process of compression is significantly more efficient when equated with the spark plug process, resulting in greater fuel economy for diesel engines (Agarwal & Das 2001)

Original diesel engines ran exclusively on vegetable oil, however in the 1920s, the feed-stock, progressed to petroleum distillates refined from crude oil during gasoline production. The benefits of so-called petrodiesel were cheaper prices, higher product availability, lighter mass and less environmental damage. Automakers were required to revise engine designs accordingly and vegetable oil as a fuel source was side-lined for decades. Fifty three years later in 1973, the oil crisis increased gas and diesel prices four fold, sparking a re-interest in bio fuels (Borgman 2007). However the viscosity of vegetable oil was too thick to function in modern day diesel engines, it plugged the injection systems and didn't spray consistently into compression cylinders. Short of

returning to older engine designs, the two options were to either heat the oil with an on-board process making it less brutal, or to reduce the molecule size. The latter option led to biodiesel, where most producers choose the manufacturing method of transesterification.

Transesterification combines oil and alcohol in the presence of a catalyst, commonly sodium hydroxide. Reaction of the fatty acids and alcohol create biodiesel and a by-product of glycerine. The most common alcohol used is methanol, yielding a biodiesel consisting of fatty acids and methyl esters. Transesterification is the most commonly used method of biodiesel production. In the United States soybean oil accounts for almost 90% of the biodiesel however any kind of vegetable or animal fat is suitable. Many scientists tend to dismiss the notion that biodiesel requires more fossil fuel energy to make (in terms of chemical inputs, labor, transportation and other factors) than it generates as a fuel.

## **1.2 PROBLEM STATEMENT**

As the price of crude oil increases day by day, many people are switching to biodiesel in order to save money and decrease the dependence on fossil fuels. Unlike fossil fuels, biofuels are produced from sustainable products such as wheat and corn and when compared to fossil fuels, is much more dependable in the long run. Despite the advantages of biofuels, there are certain complicating aspects, and biofuels often carry a heavy price. In the current market biofuels are expensive to produce and as of recently, the interest and capital investment being put into biofuel production is fairly low however has managed to match the demand. If the demand does increase, then increasing the supply will be a long term operation which will require a high level of expenditure. It is this disadvantage that is preventing the use of biofuels at a greater consumption level.

Biofuels are produced from plants and crops that contain high levels of sugar. However many of these crops are simultaneously used as food crops. Even though plant waste product can be used as raw material, the demand for these foods will still exist,



taking up the agricultural space needed for other crops and resulting in a number of problems. Even if this doesn't create the acute shortage of food, there will be pressure put on the current growth of crops. The increasing demand for these crops for both biodiesel and physical consumption is causing farmers to question whether the growing use of biofuels will cause an increase in food prices.

So to reduce the price load in producing biodiesel and to stop using food crops as biodiesel feedstock, the only solution is to use reuse wasted products. In our daily life we produce gallons of waste cooking oil which we throw away after certain time of usage. This improper disposal of wasted oil can damage the environment. Instead of disposing this wasted oil it can be used to produce biodiesel. As for the heterogeneous catalyst, rather than using processed catalyst which would consume more money, cockle can be used. By replacing the feedstock to waste cooking oil and using cockle as the catalyst, the financial burden of biodiesel production can be cut down.

### **1.3 OBJECTIVE**

The objective of this research is to:

- i ) Study the variables such as catalyst concentration, methanol to oil ratio, and reaction time that influence the yield production of biodiesel.
- ii ) Produce biodiesel from waste cooking oil (WCO) using cockle as waste heterogeneous catalyst using conventional method.
- iii ) Compare the properties of the end product with standard specification for biodiesel fuel blend stock for middle distillate fuels (ASTM D6751).

## 1.4 SCOPE OF RESEARCH

To achieve the objective of this research, there are three scopes that have been identified:

- i ) To use waste cooking oil for biodiesel production.
- ii ) To use base catalyzed transesterification to produce biodiesel.
- iii ) Using cockle (CaO) as catalyst for biodiesel production.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 BIODIESEL

As vegetable or animal fat – based diesel fuel has the molecular structure of long-chained alkyl (methyl, propyl or ethyl) esters, produced through the process of transesterification from animal or vegetable fat that is combined with alcohol. Biodiesel can be used both solitarily as well as combined with a petroleum based diesel as an alternative efficient fuel. Biodiesel can be used as a fuel or can be blended with petroleum based diesel for diesel engines. Common biodiesel blends are: B2 (2% biodiesel) and 98% petroleum diesel), B5 (5% biodiesel and 95% petroleum diesel), and B20 (20% biodiesel and 80% petroleum diesel). (Balat, 2010). In comparison to petroleum based diesel, biodiesel is much highly regarded as the better option. This is due to its highly beneficial; characteristics such as: its renewability, biodegradability, non-toxic features. Biodiesel also has reduced emission of CO, SO<sub>2</sub>, unburned hydrocarbons, volatile organic compound and particulate matter when compared to conventional diesel. (Benjumia, 2008)

Much like fuel, biodiesel has disadvantages, at 40 degree celcius , biodiesel contains a high viscosity which leads to inconvenient pumping and spraying characteristics. This, in turn can cause poor atomization, incomplete combustion and serious engine fouling when carbon deposition settles on the injector and valve seats. (Kumar, 2010., Sinha, 2008). In contradiction, biodiesel offers safety benefits when

compared to petroleum-based diesel. Its chemical characteristics enable it to be much less combustible while also harboring a flash point greater than 423 K when compared to the 350 K in petroleum-based fuel. (Balat, 2008).

## **2.2 BIODIESEL PROPERTIES**

Biodiesel is produced through the chemical reaction of vegetable or animal fat in reaction to alcohol; it is an alternative fuel to replace petro diesel. The benefits of biodiesel in comparison to petroleum based diesel the reduction of CO emission by almost 50% and CO<sub>2</sub> by 78% on a net lifecycle basis. This is because the carbon found in biodiesel emissions has the ability to be recycled from the already present carbon in the atmosphere. Petroleum on the other hand creates introduces carbon that was requisitioned below the earth's crust (Sheehan, J.,1998). Biodiesel also contains less aromatic hydrocarbons and has a cetane rate than petro-diesel, which improves both performance and clean-up emissions. Most importantly though, biodiesel is biodegradable and non-toxic. Other advantages of biodiesel include: the combination of biodiesel and petroleum diesel, eliminates the need for a high number of formal studies performed on unmodified engines and vehicles. Fuels that meet the standards and engine parts and can withstand the greater solvent properties of biodiesel are expected to run without any further problems than the use of petro-diesel.

## **2.3 BIODIESEL STANDARD**

In order for a biodiesel end product to accept as useable biodiesel, it should meet same property value which is set by the American Society of Testing and Materials (ASTM). The minimum test requirements for biodiesel property as per required in ASTM D7652 are as Table 2.1 below.

**Table 2.1:** Specification for ASTM D6751 For Biodiesel (B100)  
(Seta Biofuel Testing 2010)

| Property  | ASTM Method | Limits                         | Typical Results |
|---|-------------|--------------------------------|-----------------|
| Flash point   | D93         | 130 °C min                     | 173 °C          |
| Water & Sediment  | D2709       | 0.050% vol. max                | < 0.025         |
| Kinematic Viscosity, 40 °C                                  | D445        | 1.9-6.0 min <sup>2</sup> /sec. | 3.9             |
| Sulfated Ash  | D874        | 0.020% mass max                | 0.01            |
| Sulfur  | D5453       | 0.05% mass max                 | 0               |
| Copper Strip Corrosion                                      | D130        | No. 3 max                      | 1a              |
| Cetane  | D613        | 47 min.                        | 52              |
| Cloud Point   | D2500       | Report to customer             | -1 °C           |
| Carbon Residue, 100% Sample                                 | D4530       | 0.050% mass max                | < 0.001         |
| Acid Number   | D664        | 0.80 mg KOH/gm max             | 0.14            |
| Free Glycerin   | D6584       | 0.020% mass max                | 0.02            |
| Total Glycerin  | D6584       | 0.240% mass max                | 0.02            |
| Phosphorus Content  | D4951       | 0.001% mass max                | < 0.000         |
| Distillation Temp., atmospheric equiv. temp., 90% recovered | D1160       | 360 °C max.                    | 353 °C          |
| Specific Gravity  | D287        | Not Required                   | 0.86            |
| Dielectric Strength, KV                                     | D877        | Not Required                   | 47              |
| Color   |             | Not Required                   | Water Clear     |

## 2.4 GAS CHROMATOGRAPHY

Gas chromatography is process that can be classified as analytical separation technique which can used in analyzing volatile material in gaseous form. In performing gas chromatography, first of all the material that requires analyzing would be dissolved in a solvent so that the analyte would be separated by into two main phase, respectively, a stationary and non-stationary phase. This process plays a fundamental part in biodiesel production field as it is used to analyze the amount of Methyl Esters, Monoglycerides,

Diglycerides, and Triglycerides that present in a sample of oil. Even though the main product of biodiesel production is Methyl Ester, the incomplete reaction in between the mixture during conversion produces some contaminants (Andrade, I.C., 2013). Analysis performed by Gas Chromatography process has a great separation efficiency which allows it to recognize each and every one of these compound by its retention time which differs between one and another. Figure 2.1 shows a Gas Chromatography result.

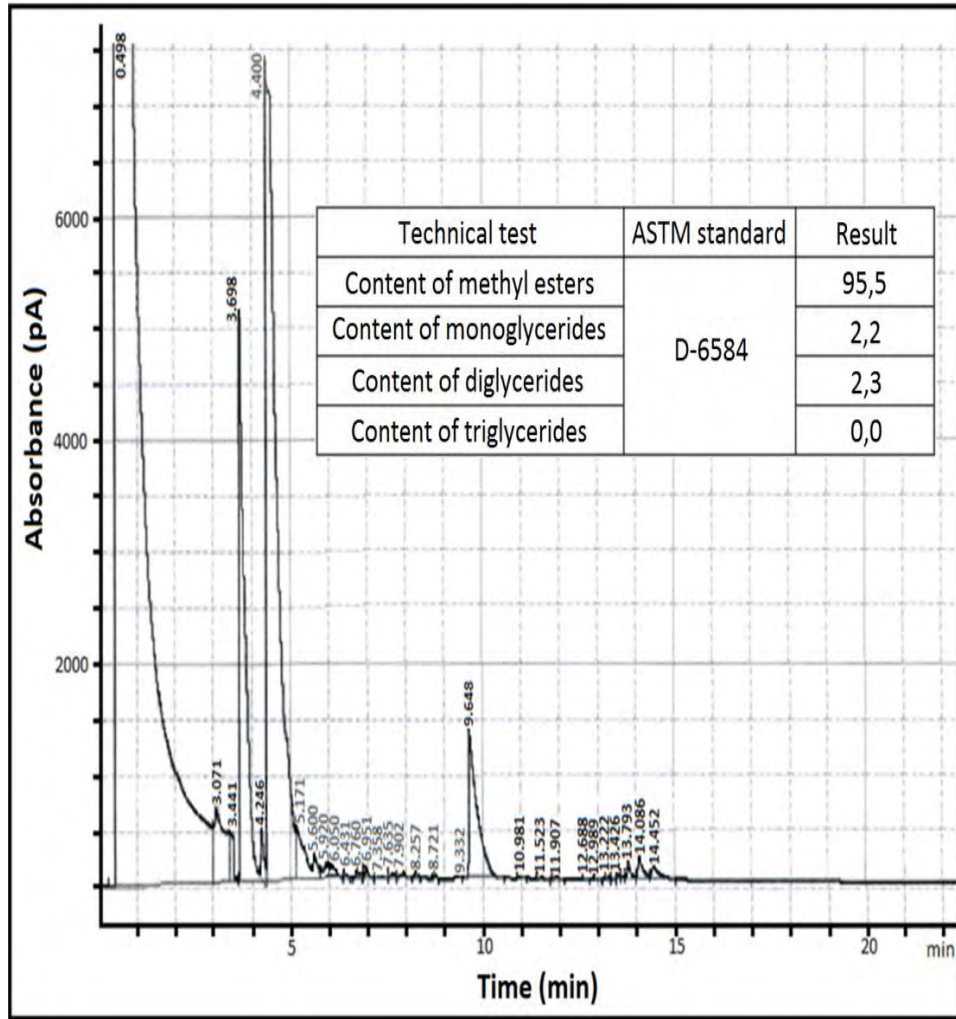


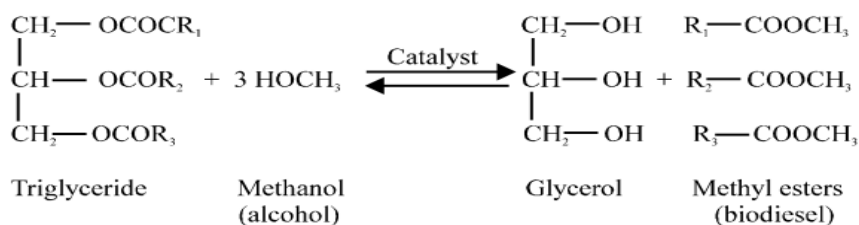
Figure 2.1: Gas Chromatography result (Andrade, I.C., 2014)

## 2.5 TRANSESTERIFICATION

Transesterification or better known as alcoholysis is a process which produces ester and glycerol when oil or fat is reacted with alcohol. One of the most widely used alcohol for transesterification is methanol due to its price which is relatively inexpensive. During the process of transesterification using methanol the amount of triglyceride will decrease while methyl ester will increase (Mittelbach and Trathnigg, 2006). The detergent and soap production all around the world have been using transesterification of glyceride with methanol (MeOH) to methylesters as the key process for the industry (Bacovsky et al., 2007).

Base catalyzed transesterification is a quite popular biodiesel production method since it is known to be less expensive and yet able to produce high conversion yield of 98% at low temperature and pressure (Rashid & Anwar 2008). Glycerin molecule acts as the base of a triglyceride molecule which has three long fatty acid attached to it. This attached fatty acid determines the characteristic of fat that is used for biodiesel production which consecutively affects the characteristic of biodiesel. Catalyst play a big role in transesterification by increasing the chemical reaction and yet no changes chemically to the catalyst itself.

In theory every mole of triglyceride needs 3 mole of alcohol so it can produce 3 mole of methyl ester together with 1 mole of glycerol as an end product (Rashid & Anwar 2008). It's likely that the transesterification process not to be optimal since the free fatty acid level has a reasonably effect in varying amount of glycerol and soap. Transesterification process is known to be a reversible process in nature. For this reason the amount of catalyst and methanol to oil molar ration should be controlled to produce a high yield. A study by (Puna J.F et al, 2013) shows that 12:1 methanol to oil molar ratio with 5% catalyst loading produces yield more than 80%. Figure 2.1 shows the chemical process for methyl ester biodiesel



**Figure 2.2:** General equation of transesterification (Nurfritri, I. et al., 2013)

## 2.6 WASTE COOKING OIL

All around the world, particularly in developing countries massive amount of waste cooking oil and animal fat are produced every single day. Managing such enormous quantity causes a big challenge because an unplanned disposal would create a possible underground water source and land contamination problem. Although some of this waste oils are used by soap manufacturers for soap production, a large portion of these oils is still discharged to the environment. The best way to manage these wasted products wisely and at the same time produce something useful is to produce biodiesel. Since one of the main disadvantages of biodiesel production is the price of feedstock, processing waste cooking oil to biodiesel considerably boosts the economic sustainability of biodiesel production.

## 2.7 RAW MATERIAL AND BIODIESEL PROPERTIES

### 2.7.1 ACID VALUE

Natural degradation of fats and oil products are normally known as the free fatty acid which is measured with the means of Acid Value number of biodiesel. the high acid value is a sign of improper manufacturing of the fuel. It is also another sign of the fuel has gone through oxidation. If the acid value is found to be more than 0.50 normally it