CHARACTERIZATION OF BIODIESEL PRODUCTION FROM *MORINGA OLEIFERA*

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CHARACTERIZATION OF BIODIESEL PRODUCTION FROM *MORINGA OLEIFERA*

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Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering (Gas Technology).

Signature :
Name of main supervisor : DR. Eman N. Ali
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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Dedication

I dedicate this thesis for my family for support me with affection and love and their dedicated partnership for success in my life

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Abstract

The combustion of fossil fuel lead to releases various type of gases like carbon dioxide, carbon monoxide and other toxic gases that can cause air pollution. When there is a significant rise in the percentage of carbon dioxide in the air, the amount of heat captured by the carbon dioxide gas also increases. This is turn leads to overall rise in the surface temperature of the earth which known as global warming. Biodiesel is now being recognised as one alternative to replace fossil fuel. Biodiesel is a renewable, degradability and environmentally friendly resources. It is produced from vegetable oils, animal fats or waste cooking oils and can be used in existing diesel engine without any expensive modification. Although biodiesel produces less emission than fossil fuel diesel, it requires investigation and evaluate some properties and chemical composition of the oil, as well any potential application in biodiesel production. This paper present the properties of biodiesel production from *Moringa oleifera* seeds as a candidate for biodiesel production. *Moringa oleifera* is considered as a versatile plant due to its multiple uses. *Moringa oleifera* also has been found to be potential new sources of oil and this plant sill one of the under explored plants and there is lack of information about physic-chemical properties of the seed oil which has limited their applications. Extraction method is used to extract the *Moringa* oil by using Soxhlet and n-hexane as a solvent. *Moringa oleifera* biodiesel is obtained by a transesterification process with methanol and potassium hydroxide as catalyst. The biodiesel properties are measured using ASTM methods. The results showed that *Moringa oleifera* biodiesel have cetane number of 67, kinematic viscosity value is 4.8 mm^2/s, 165 °C for the flash point and density is 875 kgm^{-3}. The cloud point and pour point for *Moringa oleifera* methyl ester are 18 °C and 17 °C respectively and the acid value is 0.41 mg KOH/g.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Material
EN	European standard
KOH	Potassium hydroxide
MOMEs	*Moringa oleifera* methyl esters
MOSO	*Moringa oleifera* seed oil
GC/MS	Gas Chromatography-mass spectrometry

1 INTRODUCTION

1.1 Motivation and statement of problem

Energy is a key element of the interaction between nature and society and is consider as a main input for economic development. However, energy is define as a maximum obtainable potential of work of an energy or energy flow in relation to the reference environment. Nowadays, main energy source generated from fossil fuels. Fossil fuels as the name suggests are derivatives of plant and animal fossil that are million years old. There are three fuel sources which are coal, natural gas and petroleum to supply energy and electricity. It is obvious that current use of fossil fuels in various sectors for heat and power generation continues threatening global stability and sustainability. The demands of the energy never decrease and industrial revolution shows that fossil fuel demand still going on. This energy resource is the major energy but give disastrous effects such as air pollution. When burnt, they give out carbon dioxide that leads to global warming issues. As the fossil fuels are extracted to an unlimited level it is for sure that will deplete someday. Since they are non-renewable it would take millions of year to replace oil and coal and we are not actually sure where that fuels limit is. Due to these problems, there is a need to find alternative source of energy and biodiesel is one of the solution that have been considered to solve the problems of fossil fuel depletion and degradation (Borugadda and Goud, 2012).

The use of biodiesel as a substitute for conventional diesel has been of great interest. In industry, biodiesel is not to replace the petroleum but to become another alternative source of energy. Currently, the issues of environmental pollution, global warming and depletion of fossil fuel due to demand of energy have drawn serious attention in global dimensions (Kawashima, 2009). This energy resource is the major energy but give disastrous effects such as air pollution. Biodiesel shows a favourable combustion emission profile, producing less carbon monoxide, sulphur dioxide and unburned hydrocarbons than fossil fuel (Chen et al., 2009). Biodiesel can be chemically defined as a mono-alkyl ester of long chain fatty acids derive from renewable source such as animal fats and vegetable oil (Math, 2010). Generally, biodiesel is produced through a process known as transesterification in which triglyceride are react with alcohol under acidic or basic catalytic condition. The reaction will produce glycerol and fatty acid esters of the respective alcohol.

Moringa oleifera is consider as a versatile plant due to its multiple uses. Some parts of the tree can be eaten and form part of traditional diets in many countries of the tropics and sub-tropiccs (Siddhuraju and Becker, 2003; Anhwange et al., 2004). Other than that, to its substantial uses and nutritional benefits, *Moringa oleifera* also has a great potential as a medicinal plant. Most part of this plant such as root, gum, bark, leaf, pod and seed oil has been used as a medicine in Africa and South Asia. It has been used for the treatment of cardiovascular, infectious diseases, inflammation haematological, gastrointestinal and hepatorenal disorders (Siddhuraju and Becker, 2003). The Moringaceae is a single-genus family of oilseed trees with 14 species. The most known and utilized species is *Moringa oleifera* which ranges in height from 5 to 10 m (Morton, 1991; Sengupta and Gupta, 1970). When fully mature, dried *Moringa* seeds are round or triangular in shape, the kernel is surrounded by a wooded shell and the seeds as we know can produce between 33% to 41% w/w vegetable oil (Sengupta and Gupta, 1970). *Moringa* seed oil is potential source of oil, known as Ben oil (Ndabigengeser and Narasiah, 1998). Oleic acid is the most abundant fatty acid present in Moringa seed oil (>70%) and also categorize as high-oleic acid oil. Other important fatty acid founded are palmitic (6.45%), steric (5.50%), behanic (6.16%) and arachidic (4.08%). Moreover, *Moringa oleifera* also has been found to be potential new source of oil especially with the arrival of the need for oleo-chemical and biodiesel all over the world (Anwar and Rashid, 2007). However, this plant still one of the under explored plants and there is lack of information about physico-chemical properties of the seed oil which has limited their applications.

1.2 Objectives

The objective of the study is to explore the characterizing of biodiesel production from *Moringa oleifera* seeds and compare with the standard ASTM

1.3 Scope of this research

The following are the scope of this research:

i. Extraction of oil from *Moringa oleifera* seeds.
ii. Preparation of *Moringa oleifera* biodiesel
iii. Experimental analysis of cetane number of *Moringa oleifera* methyl ester
iv. Experimental analysis of kinematic viscosity of *Moringa oleifera* methy ester
v. Experimental analysis of flash point of *Moringa oleifera* methyl ester
vi. Experimental analysis of density of *Moinga oleifera* methyl ester
vii. Experimental analysis of acid value of *Moringa oleifera* methyl ester
viii. Experimental analysis of pour point of *Moringa oleifera* methyl ester
ix. Experimental analysis of cloud point of *Moringa oleifera* methyl ester

1.4 Main contribution of this work

Moringa oleifera has gained the popularity as source of nutritional food and many country especially Africa use all the part of the tree as a food and also as a medicine. *Moringa* seed is one of the part that can produce oil. The main contribution of this work is to find alternative renewable energy resource that are clean, sustainable, and economical feasible. Biodiesel also one of the solution that have been considered to solve the problem of fossil fuel depletion and environmental degradation.

2 LITERATURE REVIEW

2.1 Introduction

In this chapter, the characteristics of the *Moringa* plant species are reviewed followed by a brief description of its cultivation. The nutritive value of the plant is reviewed and many countries especially in Africa that are interested in *Moringa* and they are also use *Moringa* aparts from their food.

This literature review also highlights the link between procedure to produce *Moringa* biodiesel and the quality and quantity of the oil produce. *Moringa* tree is not that popular tree as palm tree and also not too many at Malaysia. So, the production of the oil must be productive and quality.

2.2 Moringa oleifera: Characteristics of the plant

Moringa is a fast growing tree which can reach until 12 m in height at maturity. The tree grows with short straight stems and can reach a height of 1.5 to 2 m before it begins to branch (Rajangam et al., 2001). The *Moringa* canopy is umbrella-shaped and the branches usually grow in a disorganised manner. Figure 2.1 below show the growth structure of the *Moringa* tree.

Figure 1: *Moringa oleifera* tree

The leaves are of a compound leaf form, with three leaflets arranged on either side of the stem in pairs opposite each other, growing mostly at the branch tips. The leaves are 20 to 70 cm long with 8 to 10 pairs of pinnae and each bearing two pairs of opposite elliptic or obovate.

The fruit is green three lobed pod that hangs down from the branches and can be 20 to 60 cm in length. When dry, it opens into 3 parts. Each pod contains between 12 and 35 seeds. Thee seeds are round, with brownish semi –permeable seed hulls.

Moringa grows best in the hot semi-arid tropics. On the other hand, *Moringa* can bear light frosts. When frozen, it can sprouts fast from the trunk or ground when cut. The *Moringa* tree does well in well-drained sandy or mold soil, but the soil should not logged by water. It will tolerate a wide pH range (5-9) and grows well in alkaline condition up to pH 9. Nevertheless, it is advisable to cut trees frequently to a shrub to prevent from becoming slander and difficult to harvest. The more the tree has been cut, the bushier it becomes, with more new growth.

2.3 Nutritive value of Moringa oil

The *Moringa* seeds are round with a brownish semi-permeable seed hull. The hull itself has three white wings that run top to bottom at 120°C. Each tree can produce around 15000 to 25000 seeds/year. The average weight per seed is 0.3 g and the kernel to hull ratio is 75:25 (Makkar and Becker, 1997). Physical characterization of pods and seeds are given in Table 1.

Table 1: Physical characterization of pods and seeds

Determination	1	2	3
Average weight of pod (g)	7.60	-	7.59
Average weight of seeds (g)/pod	3.59	5.03	4.83
Average number of seeds/pod	12	17	16
Average weight (g)/100 seeds	29.9	29.6	30.2
Average weight of kernel (g)/100 seeds	21.2	-	22.5
Percent weight of kernel in relation to entire seed	72.5	-	74.5
Percent weight of hull in relation to entire seed	27.5	-	25.5
Moisture in kernel (%)	4.5	-	6.5
Moisture in hull (%)	9.2	-	12.9
Moisture in whole seed (%)	5.8	-	7.5

1. Ferrao and Ferrao (1970)
2. Carlos Foletti (1996; Personal communication)
3. Proyecto Biomass (1996)

Moringa has gained popularity as a source of nutrition as a food and save lives as well who needy (Fugile, 2001). Almost every part of this tree is of value for food. In Malaysia, the young pods are cut into small pieces and added into curries. According to Foidl, Makkar and Becker (2001), almost all parts of the tree have been utilized within traditional medicine practices and the oil can applied externally for skin problems. In Haiti and some other place use the oil in culinary and salad oil.

The oil from the seeds of *Moringa* is a high quality and can be used as a lubricant and also in cosmetics and perfumes (Fugile, 2001). Fugile (2001), also said that *Moringa* oil can be extracted in the home. Seed from the pods are roasted, crushed and placed in boiling water for five minutes. After straining and being left for a night, the *Moringa* oil floats to the surface.

Figure 2: ***Moringa oleifera*** **seeds**

Moringa oleifera seeds oil is resemble olive oil in its fatty acid composition (Ramachandran, Peter and Gopalakrishnann, 1980) and the oil is pleasant tasting with highly edible . The seed oil contains all the main fatty acids found in olive oil, therefore, can be used to substitute to the expensive olive oil. The characteristics of *Moringa oleifera* oil can be highly desirable especially with the current trend of replacing polyunsaturated vegetable oils which containing high amounts of monosaturated acids (Corbett, 2003). According to Warner and Knowlton (1997), vegetable oils with high oleic acid have been reported to be very stable even in highly demanding applications like frying.

2.4 Oil extraction

Oil extraction from seeds can be done by either chemical or physical extraction. Solvent has been use in chemical extraction while physical extraction uses a number of different types of mechanical extraction methods such as screw or ram press. Chemical extraction produces higher yields, less expensive and is used for large scale extraction process. Extracting vegetable oil from plant seeds by using organic solvents such as n-hexane, light petroleum ether, and a mixture of chloroform-methanol are more efficient (Lalas, 2002). However, the solvent residue from the oil after extraction is the major problem to eliminate it and the residue also harmful to the people and environment because of the toxic (Herrero et al, 2006).

2.5 Transesterification process

Transesterification is one of the important processes to produce biodiesel. This process happens when alcohol (methanol) displaced from ester and become methyl ester with present of catalyst (KOH). One of the popular process for producing biodiesel from fats or oils is transesterification of triglyceride by methanol to make methyl ester of the straight chain fatty acid. The purpose of the process is to lower the viscosity (Pinto, et al., 2005).

Accoding to Banerjee and Chakraborty (2009), molar ratio of methanol to oil is one of the important variables that effect transesterification. The excess of the methanol adding the oil will increase the yield of production, (Demirbas, 2008). Stoichiometrically, one mole of triglyceride and three moles of alcohol needed in this reaction to produce one mole of glycerol and three moles of fatty acid alkyl esters, therefore, ratio of the methanol to the oil must be increase to achieve best yield. Biodiesel also is not a cheap process, so that, the number of yield give important role to produce economical resources. The extraction process is one of the important processes to give a good yield production. According to Treybal (1980), extraction at the higher temperature will decrease the oil yield due to low solvent density in the sample. Thus, solvents that heating above their boiling points do not improve the oil yield, (Papamichail et al., 2000).

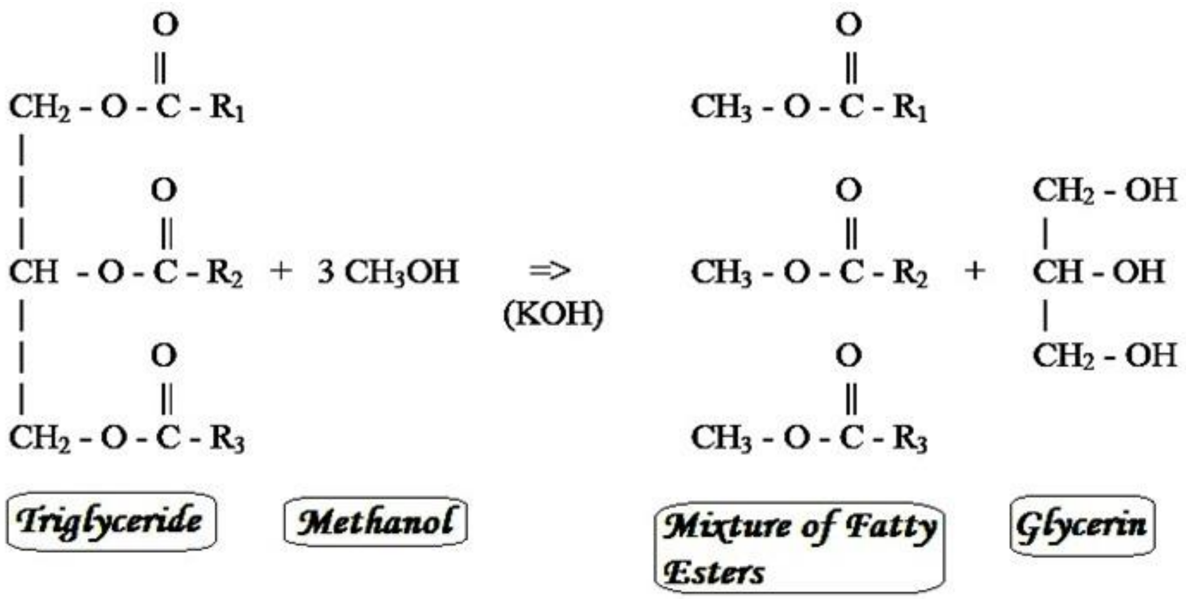

Figure 3: Transesterification process

Several methods for production of biodiesel have been developed by scientists. In these methods, the tranesterification process is carried out in the presence and absence of catalyst. A strong alkali, a strong acid, and an enzyme are three kinds of catalysts which can be used in the transesterification reaction. When we use a strong alkali as a catalyst, the transesterification process reaction become shorter and less amount of catalyst required. Therefore, almost all mass biodiesel industry used a strong alkaline catalyst (Duz, Saydut and Ozturk, 2001). Sodium hydroxide, potassium hydroxide and sodium methoxide are the most common homogeneous base catalysts employed during alkaline transesterification (Demibas., 2009).

According to Mittelbach and Remschmidt (2004), alkaline catalysis is by far the most commonly used reaction type for biodiesel production. During the initial stages of the process, it is very important for the reaction mixture to be homogenized so that the transesterification can properly proceed. Regardless of which alcohol is used, some form of catalyst has to be present to achieve high yields under relative conditions. The two most common process option are either acid or alkali catalysed transesterification reaction. Table 2 gives a comparison between two different processes (Mittelbach and Remschmidt, 2004).

Table 2: Comparison between alkali and acid catalysed transesterification

Catalysis	Alkaline	Acid
Example	KOH, NaOH, LiOH	H_2SO_4
Advantages	• Lower alcohol, oil ratio 3-5:1 (mol) • Lower reaction temperature and pressure or high yield • Faster reaction time • Less corrosive to equipment means lower capital costs	• Not sensitive to free fatty acids in feedstock
Disadvantages	• Very sensitive to free fatty acids in feedstock – needs more pre-treatment of waste oils	• Requires higher temperature, pressure and volume of alcohol • Slower reaction times • Corrosive material • Very sensitive to water in feedstock

3 MATERIALS AND METHODS

3.1 Introduction

In any research on producing biodiesel, the methodology should include the extraction of the oil and the transesterification process. In this chapter, a description on details about to produce biodiesel and determination of properties has been provide in other to archive the objective. These are following the scope of the study.

3.2 Materials

All chemicals and reagents used in this study such as n-hexane, methanol and potassium hydroxide were obtained from Merck Chemical Company. The *Moringa oleifera* seeds are collected from the village area Gambang, Pahang.

3.3 Method

3.3.1 Oil extraction from Moringa oleifera seeds

The seeds were collected during May and June 2013 from trees. At this time, the seeds are in dried condition. The seeds were crushed by using mortar and pestle after removed the seed coat. After the removal of the seed coat, 30 g of the seed were put in to the cellulose thimble and ready to extract by using Soxhlet extractor fitted with 500 mL round bottom flask. Then, 300 mL of n-hexane, an extracting solvent was poured in to the bottom flask. After extraction for 2 hours, the excess hexane was removed at 65 °C under vacuum by using rotary evaporator. The figure 3.1 and figure 3.2 is the Soxhlet extractor and rotary evaporator respectively.

Figure 4: Soxhlet extractor

Figure 5: Rotary evaporator

3.3.2 *Transesterification reaction using KOH*

The biodiesel production is carried out by using methanol and potassium hydroxide as a catalyst to increase the reaction rate and the transesterification reaction yield. In our experiment, there are 3 differences parameter consisted of temperature, reaction and alcohol weight ratio in order to find the optimum yield. The catalyst concentration remained constant with 1% weight ratio. The temperature was ranging at 30 °C, 45 °C, 60 °C and the time of reaction was 45 minutes, 60 minutes and 75 minutes. Furthermore, for the alcohol weight ratio were 20%, 35% and 50% of the oil. Reaction were performed in a 250 mL conical flask and a magnetic stirrer. 20 gram of *moringa* oil was put into the conical flask. The oil was heated until reached the desired temperature on a hot plate. At the same time, the potassium hydroxide was mixed with the methanol until the potassium hydroxide totally dissolved. After the oil reached at the desired temperature, the mixture of alcohol and catalyst was added into the conical flask. The time will be taken as the starting time. After the reaction complete, the mixture was cooled to room temperature without agitation to lead separation of two phases. The lower phase contained glycerol, excess methanol and catalyst while upper phase contained primarily of *Moringa oleifera* methyl ester (MOMEs). Figure 3.3 shows the transesterification process.

Figure 6: Extracted pure oil

Table 3: Experimental design for the transesterification of *Moringa oleifera* oil

No exp	Temperature	time (min)	Methanol (wt%)
1	30	45	20
2	30	60	20
3	30	75	20
4	45	45	20
5	45	60	20
6	45	75	20
7	60	45	20
8	60	60	20
9	60	75	20
10	30	45	35
11	30	60	35
12	30	75	35
13	45	45	35
14	45	60	35
15	45	75	35
16	60	45	35
17	60	60	35
18	60	75	35
19	30	45	50
20	30	60	50
21	30	75	50
22	45	45	50
23	45	60	50
24	45	75	50
25	60	45	50
26	60	60	50
27	60	75	50

3.3.3 Washing process

Washing biodiesel with water is the most common method of cleaning biodiesel. It takes several washes to clean biodiesel. The ester was washed with deionized water at 50 °C continuously until the water become clear. The Figure 3.5 shows the washing process of MOMEs before and after.

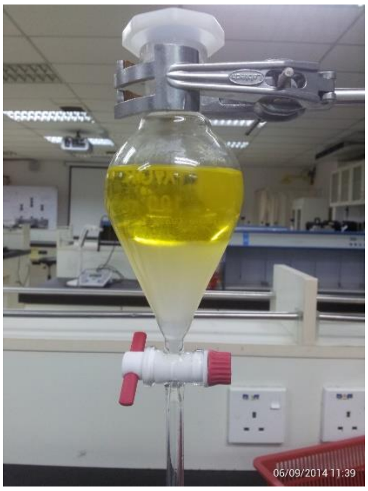

Figure 7: Before washing process

Figure 8: After washing process

3.3.5 Gas Chromatography test

Weigh 25 mg of the *Moringa oleifera* methyl ester and dissolve it in 0.5 mL of n-hexane. The resulting sample solution is filled in GC auto sampler vial and injected in GC/MS to analyse and identify the fatty acid methyl ester composition.

3.3.6 Characteristics and properties of biodiesel

The properties of *Moringa oleifera* as specified in Table 3 were determine following the recommended ASTM and EU methods. The following parameters will be determine; density (ASTM D 5002), cetane number (ASTM D613), and kinematic viscosity (ASTM D445). Flash point and acid value were determined according to standard ASTM D93 and ASTM D644 respectively.

Table 4: Standard ASTM D6751 and EN 14214

Property	ASTM D6751	EN 14214
Cetane number	>47	>51
Kinematic viscosity (mm^2/s;40°C)	1.9-6.0	3.5-5.0
Flash point (°C)	>93	>120
Pour point (°C)	-	-
Cloud point (°C)	-	-
Density (25°C,kgm^{-3})	-	-
Acid value (mg KOH/g)	0.5 max	0.5 max

3.3.6.1.1 Kinematic viscosity

30 ml of the sample was pour into the capillary tube. The sample pumped until it reach above the starting line. As the sample reach the starting line, the time is started and recorded. The time was stop when the sample reached end point line. The time recorded is the efflux time (mm^2/s^2) which must be multiply with viscometer constant, 0.4899 mm^2/s^2).

3.3.6.1.2 Cloud point and Pour point

The samples were placed in a temperature-regulated chiller bath. Removed the test jar and observed the bottom of the sample at every 1^{o}C decrease in sample temperature. The temperature was recorded after the first wax crystal forms and the temperature is Cloud point. Removed the test jar and held horizontally at every 3^{o}C decrease in sample temperature until no surface movement. The temperature recorded was Pour point.

3.3.6.1.3 Acid value

10 g of sample was prepared and mixed with 50 ml of ethanol. Setting up the mode of the Biodiesel Rancimat equipment and select "AN" method. The mixture was diluted by the titrant, Potassium Hydroxide about 10 minutes. The acid value of the sample will displayed at the monitor.

3.3.6.1.4 Cetane number

The sample was poured into the imitator and the Portable Petroleum Analyzer will calculate the cetane number. The result was appeared on the screen of the portable.

4 Result and Discussion

4.1 Introduction

The analysis of the findings discussed in this chapter will take lead from the objectives that have been set in Chapter 1. In this chapter, the result of the properties of *Moringa oleifera* have been provided. The properties have been compare by biodiesel of palm oil.

4.2 Result

4.2.1 Physical and chemical properties of MOMEs

The *Moringa oleifera* oil was light golden yellow in colour and liquid at room temperature. In this study, data analysis were taken from biodiesel of extracted *Moringa* oil. All the method for analysis based on ASTM D6571 and EN 14214 (Ong et al, 2011). ASTM D6751 identifies that the parameters of pure biodiesel should fulfil before being used as pure fuel. Furthermore, EN 14214 used as the minimum requirements for fatty acid methyl ester (FAME). The MOMEs analysed results are shown in Table 5.

Table 5: Properties of MOMEs with comparison to biodiesel standards.

Property	MOMEs	ASTM D6751	EN 14214
Cetane number	67	>47	>51
Kinematic viscosity (mm^2/s;40°C)	4.8	1.9-6.0	3.5-5.0
Pour point (°C)	12	-	-
Cloud point (°C)	18	-	-
Density (25°C,kgm^{-3})	875	-	-
Acid value (mg KOH/g)	0.41	0.5 max	0.5 max

4.3 Discussion

4.3.1 Kinematic viscosity

Kinematic viscosity is described as the resistance of liquid to flow. The viscosity refers to the thickness of the oil and determined by measuring the amount of time taken for the oil to pass through an orifice of a specific size (Nakpong, 2010). The viscosity of fuels is important for the estimation of optimum storage, handling and operational conditions. High viscosity may lead to the formation of soot and engine deposits due to insufficient fuel atomization. Besides that, lower viscosity is easy to pump and achieve final droplets to injector (Demirbas, 2008). According to Demirbas, 2008, biodiesel has viscosity close to diesel fuel. The kinematic viscosity at 40 °C of MOMEs was 4.80 mm^2/s. Thus, the result showed the value of viscosity still in range of standard and can negatively affect the volume flow and injection spray in the engines.

4.3.2 Cloud point and pour point

The cloud point is the temperature at which a sample of oil starts to become cloudy, when cooled under the specified condition. The pour point is defined as the temperature at which the amount of wax out of solution (Attabani, 2012). At low temperatures crystals of paraffins form in fuel imposing restrictions on its use. A few degrees below the temperature at which the crystals first appear, and it is Cloud point and a crystal network develops in the fluid preventing it from flowing and leading to its Pour point. Both cloud point and pour point are important for low-temperature applications for fuel. In general, diesel fuel has lower cloud point and pour point than biodiesel which is mean higher proportions of saturated fatty acids indicate that higher pour point of biodiesel (Knothe, 2005). However, the freezing point of biodiesel fuel increases with increasing carbon atoms in the carbon chain and decrease with increasing double bonds (Kumar, 2011). From Table 5, MOMEs have relatively high cloud point and pour point which are 18 °C and 12 °C respectively. As we can see from the result, MOMEs suitable to be used in cold weather countries as a MOMEs have high cloud point temperature.

4.3.3 Cetane number

The cetane number of *Moringa oleifera* methyl esters was determined to be 67.0 by using Portable Petroleum Analyzer. MOMEs come out to be a biodiesel fuel with one of the highest cetane number reported for a biodiesel based on previous research and this has been proved when biodiesel of palm oil has lower cetane number than MOMEs. In this study, *Moringa oleifera* biodiesel fulfil the minimum cetane number requirement in both the ASTM D6751 and EN 14214 biodiesel standard, which are 47 and 51 respectively.

The cetane number provides a measure of the ignition characteristics of diesel fuel oil in compression ignition engines. A higher cetane number, indicating a shorter ignition delay time and more complete combustion of the fuel. It may be noted that the heat of combustion of MOMEs is well between the ranges of other biodiesel fuels.

4.3.4 Density

Density is the relationship between the mass and volume of a liquid or solid and can be expressed in units of grams per liter (g/L). It is an important biodiesel parameter, with impact on fuel quality. Density is used to calculate the precise volume of fuel necessary to supply a sufficient combustion (Ramirez, 2013). The effect of density in engine operation is very important to injector nozzle. This can affect the efficiency of the fuel atomization for airless combustion systems (Uriate, 2010). From table 5, it has been found that MOMEs has higher density value of 875 kg/m^3 at temperature 25 °C than palm oil which has 864.42 kg/m^3. The slightly high density of biodiesel will leads to poor vaporization and incomplete combustion of the injected fuel (Cnakci, 2008).

4.3.5 Acid value

Acid value indicates the proportion of free fatty acid present in an oil or fat and also defined as the number of milligram of potassium hydroxide required to neutralize the acid in 1 gm of the sample. Acid number can be an indicator to the level of lubricant degradation while the fuel is in service (Atabani et.al, 2013). Acid number for biodiesel should to be lower than 0.5 mg KOH/g in both ASTM D6751 and EN 14214 standards fuels. The acid number is used as a guide in the quality control of lubricating oil formulation. Based on Table 5 above, MOMEs has high acid value which is 0.41 mg KOH/g.

5 Conclusion

5.1 Conclusion

World biodiesel production is on the increase due to rising crude oil price, decreasing fossil fuel and environmental concern. Malaysia have to improve the study about biodiesel and join global biodiesel producers as it would decrease its dependence on fossil fuels, promote renewable energy, decrease pollution and Malaysia have many source of vegetables and fruits that can produce biodiesel.

Biodiesel produced from vegetable oil is seen as the ideal source to replace fossil fuel in Malaysia. The technology for biodiesel production is known and available but the question is how far the quality of the biodiesel base on the properties of the biodiesel production.

Palm oil is the primary oil source production in Malaysia because of large number of palm tree. *Moringa oleifera* has been found potentially to be a good biodiesel production after the palm oil. Biodiesel is prepared from *Moringa oleifera* oil by alkali-catalyzed transesterification with methanol after acid pre-treatment. Properties such as cetane number, kinematic viscosity, flash point, density, acid value cloud point and pour point are determined. The properties are 4.8 mm^2/s for kinematic viscosity, 165°C of flash point, 875 kgm^{-3} of density and 0.41 mg KOH/g for the acid value. The cloud point and pour point of MOMEs are 18°C and 17°C respectively. The most conspicuous property of biodiesel from *Moringa oleifera* is the high cetane number expected of approximately 67. Thus, biodiesel from *Moringa oleifera* oil is suitable substitute for fossil fuel and compared to biodiesel from other vegetable oil.

5.2 Future work

The research carried in this project is currently being expanded for comparison between characteristics between *Moringa oleifera* methyl ester with the palm oil methyl ester. We can get the best biodiesel to use in Malaysia from the research. Other than that, we can also compare the properties with the current diesel that widely used in Malaysia. As we know, the oil extracted from the seeds are only 35% w/w to the weight of the seeds. So to increase the oil produce from the extraction, we can use big scale of extractor

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