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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical and Manufacturing Engineering Technology

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BACHELOR OF Mechanical ENGINEERING TECHNOLOGY (Automotive Technology) WITH HONOURS

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Fuel Properties Of The Biodiesel Blends Produced From Waste Cooking Oil (WCO)

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A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours

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2022

DECLARATION

I declare that this Choose an item. entitled " Fuel properties of the biodiesel blends produced from waste cooking oil (WCO)" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : TAN ZHENG JING

Date : 28/01/2022

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours.

Signature :

Supervisor Name : PN SUSHELLA EDAYU BINTI MAT KAMAL

Date : 28 January 2022

DEDICATION

My dissertation is dedicated to my family and many friends. I owe a special debt of appreciation to my beloved parents, whose words of encouragement and insistence on perseverance still sing in my ears. This dissertation is also dedicated to my numerous friends and church family members who have helped me during the process. Sasidharan for the grammar checking and correction, Low Yee Huat for the helping hand when I am facing problem with my laptop and my internet connection, and Jonathan for some assist for using words.

Abstract

Biodiesel is a good alternate to replace or reduce the use of commercial diesel. It has a very good characteristic which make it suitable and has potential to be implement and to be use in Malaysia. Biodiesel can reduce the pollution created by commercial diesel. However, in order to prove that it is suitable to be use, it's properties must be find out and compared with the test standards. It has capability issues with certain materials, is inherent, instable and highly corrosive. In this study, the fuel properties (acid value, density, flash point) of the biodiesel blends produced from waste cooking oil (WCO) was carried out. Biodiesel used in the experiment are in pure form (B100), and blended with commercial diesel in the form of B10 (10 percent biodiesel, 90 percent commercial diesel), B20 (20 percent biodiesel, 80 percent commercial diesel), B30 (30 percent biodiesel, 70 percent commercial diesel). From the result, we know that only B10 pass the acid value test which is lower than 0.5mhKOH/g. For the density test, all of the biodiesel blends have passed with all of it lower than the reading of 880 kg/m^3. And for the flash point, the result seems promising where all of them falls around 88°C to 98°C.it is also found that the BHT added to the B10 biodiesel blend improve the properties of the biodiesel blend produced from waste cooking oil (WCO).

ABSTRAK

Biodiesel adalah alternatif yang baik untuk menggantikan atau mengurangkan penggunaan diesel komersial. Ia mempunyai ciri yang sangat baik yang menjadikannya sesuai dan berpotensi untuk dilaksanakan dan digunakan di Malaysia. Biodiesel boleh mengurangkan pencemaran yang dihasilkan oleh diesel komersial. Walau bagaimanapun, untuk membuktikan bahawa ia sesuai untuk digunakan, sifatnya mesti diketahui dan dibandingkan dengan piawaian ujian. Ia mempunyai masalah keupayaan dengan bahan tertentu, adalah wujud, tidak stabil dan sangat menghakis. Oleh itu, ujian sifat bagi biodiesel dan bahan tambahan dijalankan untuk mencari nilai asid, ketumpatan dan takat kilatnya. Biodiesel yang digunakan dalam eksperimen adalah dalam bentuk tulen (B100), dan diadun dengan diesel komersial dalam bentuk B10 (10 peratus biodiesel, 90 peratus diesel komersial), B20 (20 peratus biodiesel, 80 peratus diesel komersial), B30 (30 peratus). biodiesel, 70 peratus diesel komersial).

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LIST OF SYMBOLS AND ABBREVIATIONS

Mt - Megatonne

Mha - Million-hectare meter

Kg - kilogram

ha - hectare

mgKOH/g - Acid value

Kg/m^3 - Kilogram per meter cube

ppm - parts per million

°C - Degree celsius

FFA - Free fatty acid

BHT - Butylated hydroxytoluene

WCO - Waste cooking oil

B100 - Pure biodiesel

B2 - Diesel with 2 percent of biodiesel blended

B5 - Diesel with 5 percent of biodiesel blended

B10 - Diesel with 10 percent of biodiesel blended

B20 - Diesel with 20 percent of biodiesel blended

B30 - Diesel with 30 percent of biodiesel blended

D2 - Euro 2 petroleum diesel

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CHAPTER 1

INTRODUCTION

1.1 Background

In order to prevent pollution on the planet, more and more products focused on the issues of earth health are being developed these days. Biodiesel is an example of a product that was developed to replace commercial diesel and minimize pollution. Straight vegetable oil, animal oil/fats, tallow, and waste cooking oil are all used to make biodiesel. Transesterification is the process of converting these oils into Biodiesel. Oil crops such as rapeseed, palm, and soybean provide the largest available source of usable oil. The majority of biodiesel currently generated comes from waste vegetable oil supplied from restaurants, chip shops, and industrial food processors. Despite the fact that oil directly from the agricultural business has the greatest potential, it is not produced commercially since the raw oil is too expensive. It is simply too expensive to compete with fossil diesel if the cost of conversion to biodiesel is included in. Waste vegetable oil is frequently available for free or at a low cost if it has already been processed. In addition, the waste oil collected must be processed to remove contaminants before being converted to biodiesel. As a result, biodiesel made from waste vegetable oil has the potential to compete with fossil fuel.

In comparison to petroleum diesel, biodiesel emits fewer hazardous chemicals and greenhouse gases. It can be used in its pure form or blended with petroleum-based diesel in the following forms: B2 (2 percent biodiesel, 98 percent petroleum diesel), B5 (5 percent biodiesel, 95 percent petroleum diesel), B20 (20 percent biodiesel, 80 percent petroleum diesel), B30 (30 percent biodiesel, 70 percent commercial diesel) and B100 (pure biodiesel). Emissions and greenhouse gas reduction with lower exhaust emissions of biodiesel is helping to reduce pollution and improve health. Biodiesel's lower CO2 emissions also help to mitigate the effects of global warming. Although biodiesel can help with some of the issues, it will also exacerbate others, such as food scarcity. Because biodiesels are derived from animal and vegetable fat, increased demand for these food products will likely drive up costs, causing a food crisis in some areas. Because biodiesel gels in cold weather, it may not be suited for certain of the world's colder climates. However, the temperature at which it gels is dependent on the oil or fat that was used to manufacture it. In addition, biodiesel can destroy various engine parts, necessitating more frequent engine replacements than those who use conventional diesel. For example, it can considerably damage the rubber houses of the engines, such as the oil seals on the fuel pump.

1.2 Problem Statement

As a renewable, sustainable and alternative fuel for compression ignition engines, biodiesel instead of diesel has been increasingly fuelled to study its effects on engine performances and emissions in the recent 10 years. In general, biodiesel are made from natural, renewable sources such as new/used vegetable oils and animal fats using a transesterification process to further obtaine pure biodiesel. Biodiesel can be used in its pure form or blended with petroleum-based diesel in the following forms: B2 (2 percent biodiesel, 98 percent petroleum diesel), B5 (5 percent biodiesel, 95 percent petroleum diesel), B20 (20 percent biodiesel, 80 percent petroleum diesel), B30 (30 percent biodiesel, 70 percent commercial diesel) and B100 (pure biodiesel).However, it has an compatibility issues with certain materials, is inherent instable and highly corrosive in nature and it is found that the direct use of biodiesel and its blends could cause higher wear and corrosion to the metal parts and the rubber components of the engine when in contact. Sporadic efforts have been carried out to understand the aforementioned issues, however significant knowledge has not been obtained until yet, especially on stability of biodiesel and its behaviour. Thus, the properties of waste cooking oil (WCO) as biodiesel and their blends with diesel and additives needs to be evaluated in order to assess their potential use in automotive engine whereby a proper understanding on the properties of the biodiesel blends is necessary in order to implement the use of biodiesel blends in our country.

1.3 Research Objective

1. To investigate the acid value, density, and flash point of D2 diesel and pure biodiesel made from waste cooking oil (WCO).
2. To investigate the acid value, density, and flash point of biodiesel blend with D2 diesel fuel at three different ratios (B10, B20 and B30).
3. To evaluate the effects of Butylated hydroxytoluene (BHT) added to the waste cooking oil (WCO) produced B10 biodiesel blends, after adding a different amount Butylated hydroxytoluene (BHT) into it.

1.4 Scope of Research

In this project, we are carrying out various test to investigate properties of biodiesel which includes the acid value, density, and flash point. First, the biodiesel made of waste cooking oil properties is studied. This substance needs to have almost the same chemical properties as commercial diesel in order to maintain its performance while in usage. In order to improve the performance of biodiesel, a few percentages of are mixed with commercial diesel and test is then conducted to find the most suitable percentage of biodiesel and commercial diesel to be used.

The test method we will be using are titration method for the acid value, pycnometer for density, and Pensky Martens flash point test for flash point. Test is done to D2 diesel, B10 biodiesel blend, B20 biodiesel blend, B30 biodiesel blend, and B10 biodiesel blend with Butylated hydroxytoluene (BHT) added.

CHAPTER 2

LITERATURE REVIEW

2.1 Biodiesel

Biodiesel is a form of diesel fuel manufactured from plant or animal-derived long-chain fatty acid esters. It's a drop-in biofuel, which means it'll work with existing diesel engines and distribution systems, as opposed to the vegetable and waste oils that were previously used to power converted diesel engines. Biodiesel is frequently blended with Petro diesel because most engines cannot run on pure Biodiesel without modification (typically to less than 10 percent).

Triacylglycerols are the main components of vegetable oils and animal fats. A chemical molecule made composed of fatty acid esters and glycerol is known as triacylglycerol. The triacylglycerol of vegetable oils and animal fats contains a number of different fatty acids. As a result, a single glycerol backbone might be used to link a variety of fatty acids. The numerous fatty acids contained in triacylglycerols make up the fatty acid profile of vegetable oil or animal fat. Because different fatty acids havevarying physical and chemical properties, the fatty acid profile is arguably the most essential factor influencing the attributes of a vegetable oil or animal fat.

Transesterification is a chemical reaction that is used to make biodiesel from vegetable oil or animal fat. To make the necessary alkyl esters of the fatty acid mixture found in the original vegetable oil or animal fat, the vegetable oil or animal fat is reacted with an alcohol (usually methanol) in the presence of a catalyst.

2.1.1 Feedstock for Biodiesel Production

a) Soybean

Soybean is one of the world's most significant crops, owing to the high quality of its protein meal. Although the seed's oil content (18–20%) is smaller than its protein level (36–40%), the resulting oil volume is considerable due to the massive amount of soybean meal required to feed meat animals (EMBRAPA 1994). Soybean oil was produced in around 45 Mt in 2014, second only to palm oil in terms of global production. In reality, soybean oil dominated vegetable oil production until the last decade, and it may do so again in the not-too-distant future. In 2013, Argentina produced 49.31 Mt of soybeans on 19.42 Mha with a productivity of 2539 kg/ha, Brazil produced 81.72 Mt on 27.91 Mha with a productivity of 2929 kg/ha, and the United States produced 89.48 Mt of soybeans on 30.7 Mha with a productivity of 2915 kg/ha. New industries such as bioenergy and oil chemistry, in addition to the food market for humans and pets, have expanded the horizons of soybean demand, raising annual growing rates since 1990, when worldwide production (108 Mt) was just one-third of current (315 Mt) production. Over the last 20 years, the average annual growth rate has topped 8 Mt. (Faostat 2015).

b) Oil Palm

It is also known as African palm and hails from the Gulf of Guinea in west central Africa. Although it has been known and used for millennia, commercial cultivation began in Malaysia in the first decade of the twentieth century. Palm is the oil crop that generates the most oil per hectare, accounting for 57 million tonnes of the global 170 million tonnes of vegetable oils produced. It accounts for almost 60% of global vegetable oil output, alongside soybean oil, yet when comparing the 2015 average oil yield of each crop, one hectare of palm oil delivers the same amount of oil as ten hectares of soybeans. Because of its high oil output, palm oil takes up only 8% of the world's oil crop land but produces over a third of all vegetable oil. Palm oil is grown in the humid tropics, as well as Southeastern Asia, Northwestern South America, and parts of Central America, due to its tropical origins. Asian countries now account for roughly 90% of the world's agricultural land. The main producers are Indonesia, Malaysia, and Thailand. Asia is also home to the world's largest importers. Palm oil is employed in bioenergy production, however it is most commonly used in the nutrition and cosmetics industries.

Biodiesel made from palm oil has a very favourable energy balance (input/output), sometimes as high as 1:8. The land that is now used for palm oil agriculture in Southeastern Asia was formerly covered with natural forest, resulting in massive deforestation and the collapse of the rainforest in nations like Indonesia within a decade. Brazil, on the other hand, has the world's largest reserve of suitable land for palm cultivation, estimated to be around 50 million hectares (Mha), but only cultivates 0.16 million hectares due to restrictions imposed by Brazilian environmental legislation for Amazonian lands, which limits the size of a given farm to 20% of its total area, preserving 80% of the biome. As a result, Brazil is the 9th largest producer of palm oil (0.37 Mt), resulting in continual palm oil imports. Palm oil is a large and perennial oil-producing plant.

However, after oil extraction, the wastes have little or no commercial use. Palm oil wastes are mostly used as organic fertiliser or to generate power by burning the trash. Palm oil is extracted from the pulp of palm oil fruits, and palm kernel oil is extracted from the fruit kernel. The oil fraction accounts for around 22% of the weight of the palm bunch, with palm kernel oil accounting for only 3%. Palm oil, which makes up the majority of palm kernel oil, is nearly devoid of lauric acid.

c) Rapeseed

Rapeseed is a member of the Brasscicaceae (previously Cruciferae) family, which includes mustard, broccoli, and cauliflower. The word canola comes from a contraction of "CANadian Oil Low Acid," a rapeseed variety developed in the 1970s by Canadian scientists from the University of Manitoba who selected cultivars with low erucic acid oil (toxic for humans and animals). The high quantities of erucic acid and glucosinolate in the grains distinguish rapeseed from canola. Brassica oilseed variants are among humanity's earliest cultivated plants, with evidence of their use dating back to 4000 B.C. in India and 2000 B.C. in China and Japan. During World War I, rapeseed oil was in great demand due to its lubricating characteristics, as it was needed to supply the growing number of steam engines in naval and merchant ships. After the war, the demand for lubricants fell precipitously, and new uses for oil emerged. Canola is currently the most widely produced rapeseed variety on the planet.

Canola is best known for its oil, but its meal is also highly sought for animal feed formulation due to its high protein content. According to De Morietal., canola seeds have a high oil content (38–45%), and the volume of oil produced worldwide is only surpassed by palm and soybean oil. Canola oil has a low proportion of unsaturated fatty acids, with palmitic (16:0) having the highest content (4 percent). The monounsaturated oleic (18:1) (63%) is the most abundant fatty acid in canola, followed by polyunsaturated linoleic (18:2) (20%) and linolenic (18:3) (18:3). (9 percent).

Canola biodiesel is expensive for the market and for supporting public policy due to high canola oil costs. In terms of the energy balance of biodiesel from canola oil, it was determined that for each input energy unit throughout the life cycle, 2.9 energy units are obtained; when only oil production is considered (without accounting for energy on the meal), this relationship reduces to 1:1.4. In 2014/15, global canola grain production was 72 Mt, allowing for the extraction of 26 Mt of oil, accounting for 16 percent of global vegetable oil production. The European Union (24.0 Mt) is the most productive region, followed by China (14.7 Mt), Canada (14.45 Mt), India (7.5 Mt), and Japan (2.0 Mt). Canola grain has about 40% oil, and it grows best in warm climates far from the Equator.

d) Sunflower

Sunflowers originated in the Southwest United States and Northern Mexico, from where they spread across the continent. It was most likely domesticated in that region, where evidence of North American Indian agriculture dates back over 3000 years. Biofuels: Feedstocks 27 Sunflower's rise to prominence as a globally important crop was largely due to Russia's efforts. Sunflower's importance as a source of edible oil was only discovered in the 1920s. Sunflower, on the other hand, rose to the forefront of oil crop production following WWII. In 2014, the global sunflower cultivated area was roughly 18 Mha, with an overall production of 40 Mt grain, 16 Mt oil, and 17 Mt meal, placing it fourth among the world's most important oils and meal producers. Sunflower vegetable oil accounts for roughly 7.5 percent of global production, trailing palm oil (34%), soybean oil (30%), and canola oil (30%). (16 percent). The seeds' oil content is around 45 percent, which is virtually entirely consumed as edible oil because to its high quality, and the protein level is between 28 and 32 percent.

Sunflower, according to Ungaro, requires an insensitive photoperiod and may be grown everywhere from the equator to latitudes over 40°. The ideal temperatures for efficient plant growth are between 27 and 28 °C, but it grows well from 8 to 34 °C, making it a suitable off-season crop and an essential agronomic alternative for rotation with soybeans, corn, and wheat. Unsaturated fatty acids are abundant in the oil, with monounsaturated oleic (18:1) accounting for 16 percent and polyunsaturated linoleic accounting for 72 percent; significant saturated fatty acids include palmitic (16:0), accounting for 6 percent, and stearic (18:0), accounting for 4 percent. Sunflowers are grown as ornamental plants, and its nectar is used to feed domestic bees and sillage (animal fodder).

Sunflower oil has a nutritional content similar to canola oil, making it ideal for biodiesel manufacturing. Gazzoni et al. calculated the energy efficiency of biodiesel synthesis from sunflower oil using Life Cycle Analysis methodologies. They found that for each energy unit input to the system, 2.69 units of energy were obtained with the entire grain destination (meal for nutrition, oil for biodiesel). When meal was not taken into account, the relationship was lowered to 1.61 units of energy received through biodiesel consumption for each unit of input energy.

e) Waste cooking oil

Due to the resultant increase in demand for vegetable or edible oil and unnecessary clearing of forests for plantation, the use of a food sourc e (edible oil) to produce biodiesel at the expense of the millions of people facing hunger and starvation around the world has received harsh criticism from several non-governmental organisations worldwide. Animal and plant habitats will be disrupted by deforestation.

These problems could be reduced if WCO is used as a biodiesel feedstock. Plus, there is rising worry about the impact on the environment of increased WCO production in homes and restaurants. WCO is obtained after frying numerous times with edible vegetable oils such as palm, sunflower, and corn oils. Because of the changes that occur during frying, the chemical and physical properties of WCO differ slightly from those of fresh oils. Due to the rapid growth of the human population, the amount of WCO produced by homes and restaurants is rapidly increasing. Furthermore, increased food consumption has resulted in massive volumes of WCO being produced. WCO is produced in the United States alone in the amount of 10 million tonnes per year, necessitating a cost-effective and ecologically beneficial disposal solution, such as using it as a fuel for biodiesel synthesis.

WCO is 2 to 3 times less expensive than fresh vegetable oil, resulting in a significant reduction in total processing costs. Furthermore, unlikethe usage of virgin edible oils, the use of WCO does not deplete food supplies, removing any potential controversy in the area. One disadvantage of using WCO for biodiesel production is that it contains various contaminants, such as free fatty acid and water, which must be removed prior to transesterification due to their major negative impacts on the process. The acid and saponification levels of WCO are used to determine its quality. If the free fatty acid level in the oil is greater than 3%, transesterification failure may occur.

2.1.2 Catalyst for Biodiesel Production

1. **Acid catalyst**

   Although acidic materials can be employed in transesterification reactions, the reaction rates are typically too slow, thus base catalysts are preferable. However, there have been some reports of potentially beneficial catalysts. The use of strongly acidic polymetric materials such as catalyst in the transesterification of several Brazilian vegetable oils was investigated by Lachter and colleagues. Sulfuric acid homogeneous catalysis demonstrated 44 percent conversion during an eight-hour reaction at 60°C with a 300:1 molar ratio methanol:TG, whereas extremely acidic polymeric materials showed 64 to 74 percent conversion.

2. **Natural Clays/Silicates**

   There are numerous natural clays, minerals, and silicas. These materials have received a lot of attention as catalysts in a variety of processes, including transesterification. These catalyst materials are low-cost and generally available, and they should work well in heterogeneous catalysis.

2.1.3 Biodiesel Production

Biodiesel can be made from a variety of sources, including plain vegetable oil, animal oil/fats, tallow, and waste oils. There are three basic methods for making biodiesel from oils and fats:

i. Base catalyzed transesterification of the oil.
ii. Direct acid catalyzed transesterification of the oil.
iii. Conversion of the oil to its fatty acids and then to biodiesel.

Base catalyzed transesterification is used to make almost all biodiesel since it is the most cost-effective technique, requiring just modest temperatures and pressures and yielding a 98 percent conversion yield. The reaction of a triglyceride (fat/oil) with an alcohol to produce esters and glycerol is known as transesterification. A triglyceride is made up of three long-chain fatty acids connected to a glycerine molecule. The type of the fatty acids connected to the glycerine determines the fat's properties. The type of the fatty acids can have an impact on the biodiesel's properties. The triglyceride reacts with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide, during the esterification process. The mono-alkyl ester, or biodiesel, and crude glycerol are formed when the alcohol interacts with the fatty acids. Methanol or ethanol (methanol creates methyl esters, ethanol makes ethyl esters) are the most common alcohols used in production, and they are base catalyzed by potassium or sodium hydroxide. For ethyl ester biodiesel manufacturing, potassium hydroxide has been discovered to be more suited; however, either base can be utilized for the methyl ester.

The chemical process for methyl ester biodiesel is depicted in the diagram below. Since this reaction between fat or oil and alcohol is reversible, a large amount of alcohol must be supplied to force the reaction to the right and assure total conversion.

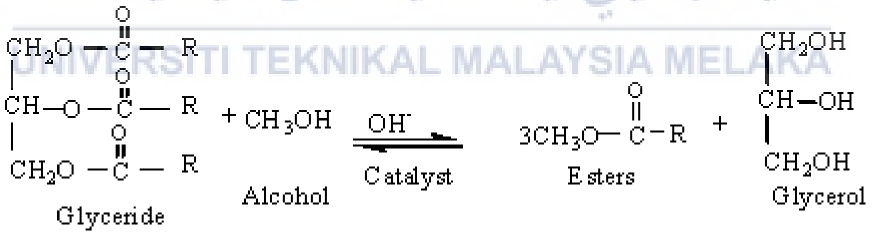


Figure 2.1.3.1 Chemical process for methyl ester biodiesel

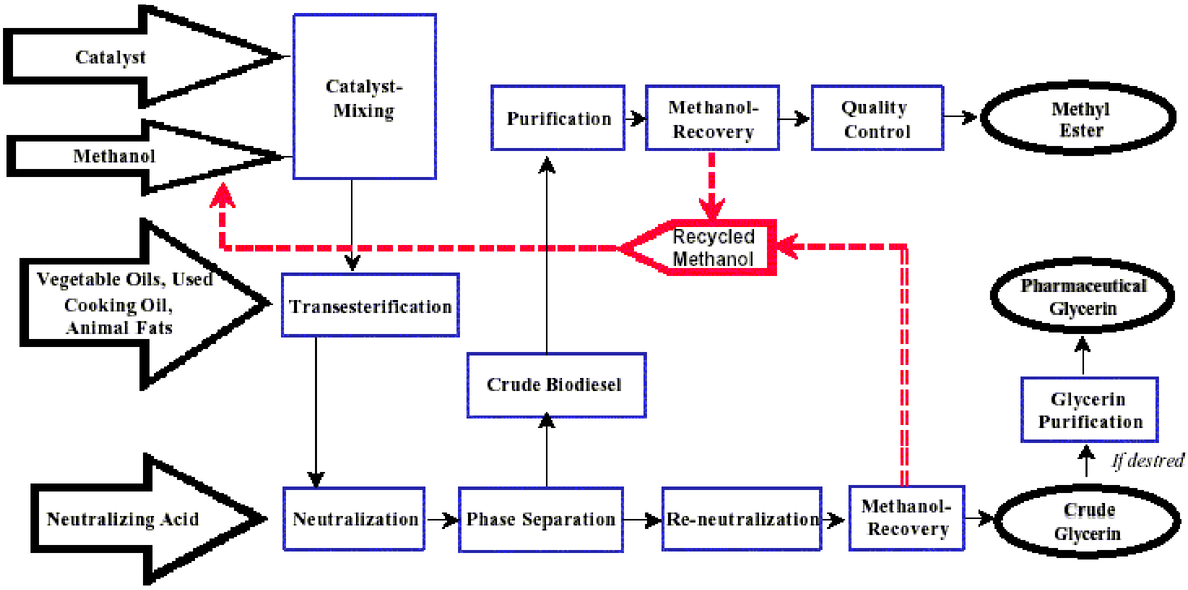


Figure 2.1.3.2 Biodiesel production flow chart

a) Mixing of alcohol

Sodium hydroxide (caustic soda) or potassium hydroxide are commonly used as catalysts (potash). A normal agitator or mixer is used to dissolve it in the alcohol. Reaction. The oil or fat is then added to the alcohol/catalyst mixture in a closed reaction tank. To avoid the loss of alcohol, the system is completely sealed from here on out. To speed up the process, the reaction mix is held slightly above the boiling point of the alcohol (about 160 °F), and the reaction takes place. The recommended reaction time ranges from 1 to 8 hours, and some systems suggest doing the reaction at room temperature. Excess alcohol is usually employed to ensure that the fat or oil is completely converted to its esters. The amount of water and free fatty acids in the incoming oil or fat must be carefully monitored. If the free fatty acid or water levels are excessively high, soap generation and the separation of the glycerin by-product downstream may be affected.

b) Separation

When the reaction is finished, two main products are produced: glycerin and biodiesel. Each has a significant amount of the extra methanol from the process. If necessary, the reactive mixture is neutralized at this point. The glycerin phase is much denser than the biodiesel phase, therefore the two can be separated by gravity, with the glycerin collected from the bottom of the settling tank. A centrifuge may be used to separate the two elements more quickly in some circumstances.

c) Alcohol removal

The excess alcohol in each phase is removed using a flash evaporation technique or distillation after the glycerin and biodiesel phases have been separated. Other procedures remove the alcohol and neutralize the mixture before the glycerin and esters are separated. In any scenario, the alcohol is recovered and reused using distillation apparatus. It's important to keep an eye on the recovered alcohol stream to make sure it doesn't fill up with water.

d) Glycerin neutralization

The unused catalyst and soaps in the glycerin by-product are neutralized with an acid and sent to storage as crude glycerin. The salt generated during this phase is sometimes collected and used as fertilizer. The salt is usually left in the glycerin. Water and alcohol are removed, leaving 80-88 percent pure glycerin ready for sale as crude glycerin. Glycerin is distilled to 99 percent purity or greater in more complex facilities and marketed into the cosmetic and medicinal markets.

e) Methyl ester wash

The biodiesel is occasionally refined once it has been separated from the glycerin by gently washing it with warm water to remove any remaining catalyst or soaps, drying it, and storing it. This stage isn't required in some processes. This is usually the last step in the manufacturing process, and the outcome is a clear amber-yellow liquid with a viscosity similar to petrodiesel. In some systems, the biodiesel is further distilled to eliminate minor amounts of colour bodies, resulting in a colourless biodiesel.

f) Product quality

The completed biodiesel must be evaluated with advanced analytical equipment before being used as a commercial fuel to verify it fits any regulatory criteria. The following are the most critical aspects of biodiesel manufacturing for trouble -free operation in diesel engines:

- Complete Reaction
- Removal of Glycerin
- Removal of Catalyst
- Removal of Alcohol
- Absence of Free Fatty Acids

2.2 Butylated hydroxytoluene (BHT)

Butylated hydroxytoluene (BHT), is a phenolic antioxidant used as a significant substrate in food and feed chemistry, medicines, and pharmacology. It's widely utilized in the plastics production and processing industries, as well as in fermentation and bio industrial chemistry. BHT can also be utilized in essential oils and cosmetics as a preservative. Since 1954, the Food and Drug Administration (FDA) has allowed BHT for use in low amounts in foods and food packaging. BHT is one of the most often used antioxidants in meals containing lipids, petroleum products, and rubber, and is recognized as safe for use in foods (Federal Register, 1977).

Apart from all of the advantages and benefits of BHT and its derivatives, this fascinating family of aromatic chemicals is well-known for its antioxidant properties. BHT is also commonly used with other antioxidants such as BHA, propyl gallate, and citric acid. In addition, by regenerating -TOH, BHT and BHA can be used as co-antioxidants. BHT and its derivatives have become desirable antioxidant or CoAH groups as a result of these numerous applications.

It is therefore, that BHT has been tweaked to create a new class of antioxidants with novel capabilities in the polymer and pharmaceutical industries.

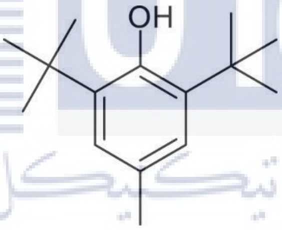


Figure 2.2 Butylated hydroxytoluene (BHT) structure

2.3 Acid value

The acid value, like kinematic viscosity, is a simple way to check the quality of the biodiesel. The acid value is calculated using the technique ASTM D664 in ASTM D6751 and ASTM D7467 and EN 14214 using the procedure EN 14104. However, D664, a potentiometric approach, has poor reproducibility, a flaw that the method itself acknowledges. The issue is most likely caused by electrode fluctuation. ASTM D974 is a non-aqueous titration that uses KOH in isopropanol and p-naphtholbenzoin as an indicator. It can be used on colored samples as well. The ASTM D974 method produced more consistent results than ASTM D664. As a result, in the biodiesel standard D6751, ASTM D974 would be the more appropriate approach than ASTM D664. EN 14104 is a titration as well, although it employs a dilute ethanolic KOH solution as well as phenolphthalein as an indicator.

Titration methods for determining the neutralization number (NN) of biodiesel are included in other literature pertaining to the acid value. Two procedures were devised for determining strong acids and free fatty acids in a single assay. Potentiometry was utilised in one method, whereas two acid-base indicators were used in the other (neutral red, phenolphthalein). The potentiometric method was more trustworthy, and even when two indicators were used, the NN values produced from the titration method were 10–20 percent higher than the sample's true acidity.

Free fatty acids in biodiesel were identified by negative ionization electrospray ionization mass spectrometry. The EASI-MS method mentioned above for determining the fatty acid profile has also been reported to be useful for free fatty acid determination.

2.4 Density

The density of a substance is its mass per unit volume (more accurately, its volumetric mass density; also known as specific mass). Density is defined mathematically as mass divided by volume:

$$\rho = \frac{m}{V}$$

where ρ is the density, m is the mass, and V is the volume. Although this is scientifically wrong, density is sometimes roughly characterized as its weight per unit volume.

The density of a pure substance is equal to its mass concentration in numerical terms. Varied materials have different densities, which can affect things like buoyancy, purity, and packaging. At ordinary temperature and pressure, osmiumand iridium are the densest known elements.

Temperature and pressure affect the density of a substance. For solids and liquids, this variance is often minimal, but for gases, it is significantly bigger. When you apply more pressure on an object, it shrinks in volume and so becomes denser. With a few exceptions, increasing the temperature of a substance decreases its density by increasing its volume. Due to the decrease in density of the heated fluid, which causes it to rise relative to denser unheated material, heating the bottom of a fluid leads in convection of heat from the bottom to the top in most materials.

2.5 Flash point

The flash point of a volatile material is the lowest temperature at which its vapours ignite when exposed to an ignition source, as defined in chemistry. The flash point is frequently confused with the autoignition temperature, which causes spontaneous ignition. The fire point is the lowest temperature at which the vapours continue to burn after the ignition source has been withdrawn. It's higher than the flash point because new vapour might not be produced quickly enough to keep the flame burning at the flash point. The temperature of the ignition source has no effect on the flash point or fire point, despite the fact that the ignition source temperature is substantially higher than the flash or fire point.

Open cup and closed cup flash point measurements are the two most used forms. The sample is contained in an open cup that is heated and a flame is brought over the surface at intervals in open cup devices. The observed flash point temperature will change depending on the height of the flame above the liquid surface, and at a suitable height, the measured flash point temperature will coincide with the fire point temperature.

Closed cup testers are divided into two types: non-equilibrial (Pensky-Martens), in which the vapours above the liquid are not in temperature equilibrium with the liquid, and equilibrial, in which the vapours are deemed to be in temperature equilibrium with the liquid. The cups are sealed with a cover through which the ignition source can be introduced in each of these types. Closed cup testers produce lower flash point values than open cup testers (usually 5–10 °C or 9–18 °F lower) and are a better indication of the temperature at which the vapour pressure approaches the lower flammable limit.

Rather of being a basic physical property, the flash point is an empirical measurement. Temperature ramp rate (in automated tests), time allowed for the sample to equilibrate, sample volume, and whether the sample is agitated are all factors that influence the observed value.

CHAPTER 3

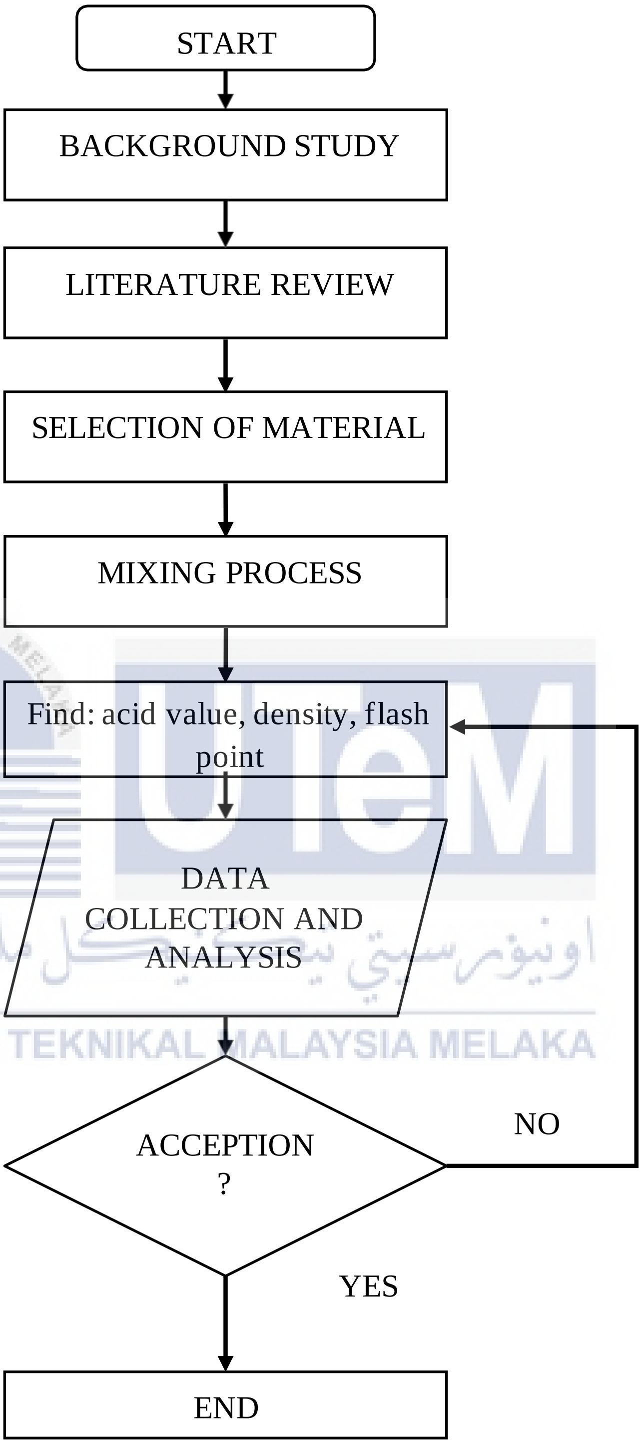
METHODOLOGY

3.1 Introduction

Biodiesel standards were first developed in the 1990s to facilitate the growing use of alkyl esters-based biodiesel and blends as motor fuels. In 1999, ASTM International (previously the American Society for Testing and Materials) issued PS121, a provisional specification for biodiesel. In 2002 [ASTM 2002], the first ASTM standard (ASTM D6751) was adopted. In October 2003, the European Union finalized the EN 14214 biodiesel standard (based on the old DIN 51606). Internationally, the US and EU requirements are important; they are frequently used as a starting point for biodiesel specifications established in other nations.

The approaches to biodiesel standards in the United States and the European Union differ. ASTM D6751 is a specification for a biodiesel mix stock for medium distillate fuels in the United States. While the specification is for B100, it is not for neat biodiesel used as an automotive fuel. Rather, it is for the biodiesel component that will be blended with diesel fuel to make biodiesel/diesel blends. The ASTM D6751 standard has specified two categories of biodiesel since 2012: grade 2-B (similar to biodiesel described by previous versions of the standard) and grade 1-B (with tighter monoglyceride and cold soak filterability limits).

3.2 Flowchart



Flowchart 3.2

The flowchart shows the flow of performing the test on the biodiesel blend. First, we need to obtain the different biodiesel blend including pure biodiesel(B100), biodiesel 90 percent and petroleum diesel 10 percent (B10), biodiesel 80 percent and petroleum diesel 20 percent (B20), and biodiesel 70 percent and petroleum diesel 30 percent (B30) was prepared following to the standard procedure. Other than that, the B10 biodiesel was mixed with three different amounts of antioxidant called Butylated hydroxytoluene (BHT). Then the test was carried out in order to find the acid value, density and the flash point of the test subjects. When all of that are finished, we can proceed to carry out the test and record the data for each biodiesel blend and determine which blend are the most suitable for the current state of the industry.

3.3 Mixing process for biodiesel

Before mixing the biodiesel and the biodiesel, we will need to heat them up using different equipment. We will need to prepare the required amount of diesel and biodiesel before heating the fuels. A measuring cylinder is used here to get a precise reading of the fuels. The measured diesel and biodiesel fuel are then hold by two different beakers.

The diesel is heated up with a stirring hotplate up until the diesel reach a temperature of 50°C. For the diesel, we will use a water bath method to heat it up. First, we will set the water bath machine to heat up until 60°C. When the water temperature has reached 60°C, we will place the beaker filled with biodiesel in the water bath machine and wait for fifteen minutes. The heating process is crucial to remove any water content in the fuel.

Then we will pour the heated biodiesel into the beaker with the diesel in the water bath and use a scientific digital lab overhead stirrer to stir and mix the diesel and biodiesel together. This process is continued for three minutes and the stirrer speed are set to 375 rotation per minute.

After the mixing process has completed, the biodiesel blend is poured and keep in the prepared glass bottle. The bottle of biodiesel blend is then rested for a night and observed in the next day if there are any stratification in it.

The total volume of the biodiesel blends are:

- B10 biodiesel blend = 640ml (576ml of D2 diesel and 64ml of B100 biodiesel)
- B20 biodiesel blend = 640ml (512ml of D2 diesel and 128ml of B100 biodiesel)
- B30 biodiesel blend = 640ml (448ml of D2 diesel and 192ml of B100 biodiesel)

Figure 3.3.1 Measuring cylinder and beaker

Figure 3.3.2 Heating biodiesel with stirring hotplate

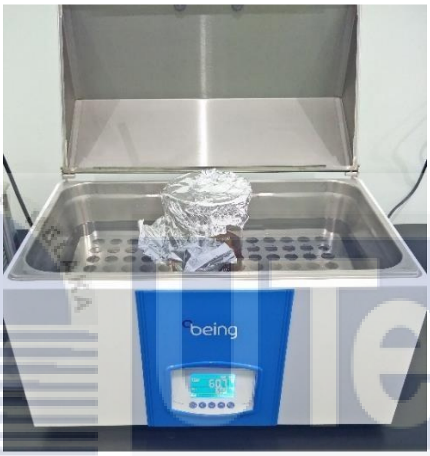


Figure 3.3.3 Heating diesel with water bath machine

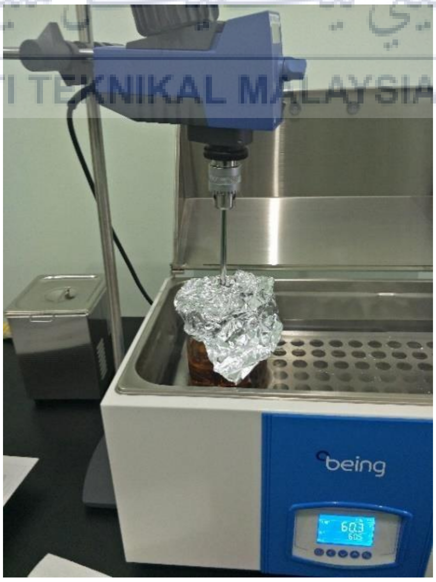


Figure 3.3.4 Stirring process using a scientific digital lab overhead stirrer

Figure 3.3.5 B10, B20, B30 biodiesel blends kept in glass bottles

3.3.1 Adding BHT into B10 biodiesel blend

In order to improve the performance of the biodiesel blend, it is decided to add a type of antioxidant called BHT into the fuel by three different amounts. The amount of BHT that are going to be added to the B10 biodiesel blend are 200ppm (0.002g), 400ppm (0.004g), and 600ppm (0.006g). The mass of the BHT is taken using a digital weighing scale in the lab measured.

$$1ppm = 1mg/l$$

The B10 biodiesel blend added with BHT is then placed in a homogenizer. Homogenizers are mixers that reduce particle size or force immiscible liquids to combine. Pump pressure or air diverse through the valves and nozzles is what decide how much pressure the homogenizer applies to a product. Fluid velocity is increased in low-pressure homogenizers, which lowers overall pressure. This step will help mix the BHT and B10 biofuel blend to mix thoroughly.

Figure 3.3.1.1 B10 biodiesel blend added with BHT in a homogenizer

3.4 Titration

There is a lot of research going on these days to generate biodiesel fuels. This substance is frequently created from discarded vegetable oils. The biofuel is made by treating vegetable oil with lye. The amount of acid in the oils must be assessed so that the workers know how much lye to add to make the final fuel. The native vegetable oil is titrated before the lye is applied to determine how much free acid is present. The amount of lye used can then be modified to account for the amount of lye required to neutralize the free acids.

In the neutralization of hydrochloric acid by sodiumhydroxide, the mole ratio of acid to base is 1:1.

$$\mathrm{HCl}(aq) + \mathrm{NaOH}(aq) \rightarrow \mathrm{NaCl}(aq) + \mathrm{H_2O}(l)$$

One mole of HCl would be fully neutralized by one mole of NaOH. If instead the hydrochloric acid was reacted with barium hydroxide, the mole ratio would be 2:1.

$$2\mathrm{HCl}(aq) + \mathrm{Ba(OH)_2}(aq) \rightarrow \mathrm{BaCl_2}(aq) + 2\mathrm{H_2O}(l)$$

To neutralize one mole of Ba(OH) 2, two moles of HCl are now required. The mole ratio ensures that the quantity of H + ions given by the acid and the number of OH ions supp lied by the base are equal. For neutralization to occur, this must be the case. In a neutralization reaction, the equivalence point occurs when the number of moles of hydrogen ions equals the number of moles of hydroxide ions.

A controlled neutralizing reaction can be used to accomplish this. A titration is an experiment in which a volume of a known concentration solution is added to a volume of another solution to determine the concentration of the latter. Acid-base neutralization reactions account for the majority of titrations, but other types of titrations are also possible.

The chemist must be able to visually recognize that the neutralizing reaction has happened in order to execute an acid-base titration. In an acidic or basic solution, an indicator is a material that changes colour dramatically. Phenolphthalein is a frequent indicator for strong acid-strong base titrations. When a few drops of phenolphthalein are introduced to a solution, the colour changes from colourless to vivid pink as the solution changes from acidic to basic. A titration reaction's steps are listed below.

1. A measured volume of an acid of unknown concentration is added to an Erlenmeyer flask.
2. Several drops of an indicator are added to the acid and mixed by swirling the flask.
3. A buret is filled with the base solution of known molarity.
4. The stopcock of the buret is opened and base is slowly added to the acid while the flask is constantly swirled to insure mixing. The stopcock is closed at the exact point at which the indicator just changes color.

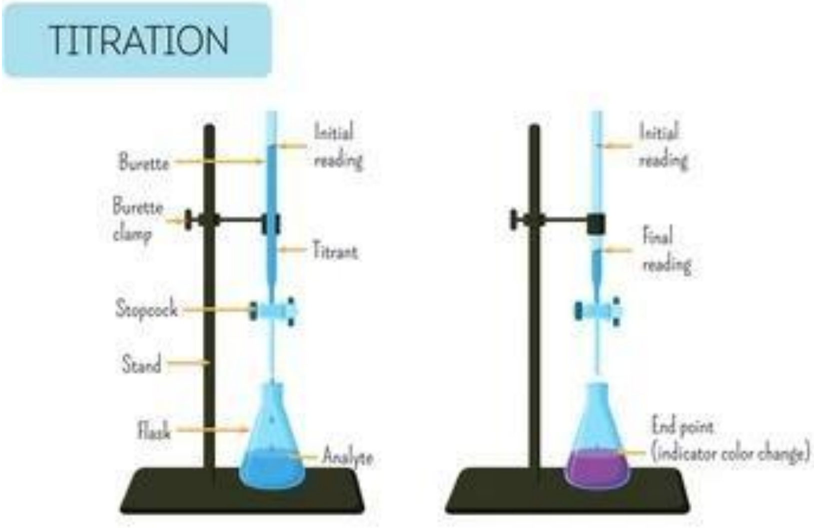


Figure 3.4.1 Titration setup

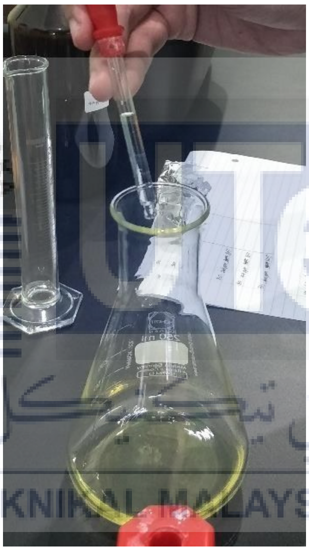


Figure 3.4.2 Adding phenolphthalein into biodiesel blend

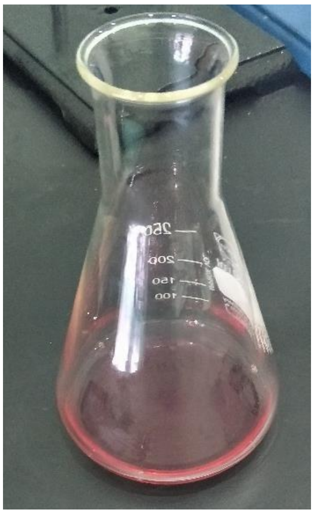


Figure 3.4.3 Biodiesel changes after the titration test

3.5 Pycnometer method

A pycnometer is a glass vessel of specific shape and volume that is used for measuring the density of substances in the gaseous, liquid, and solid states.

A pycnometer measures density by weighing a substance, usually in liquid form, that is placed in the device and fills it to a mark on its neck or the upper edge of a capillary tube, equivalent to the pycnometer's nominal volume. When the pycnometer has a scale instead of a single mark, volume measurement becomes easier. Pycnometers with a side capillary tube and a stopper that is the body of a thermometer are especially easy to use. Solids are measured in a pycnometer with a liquid to estimate their density. The density of gases is measured using pycnometers with unusual shapes, such as spherical ones.

Pycnometric method requires the glassware to be cleaned carefully with soap and water before rinsing with a little amount of acetone as directed above. On the analytical balance in the balance chamber, weigh the dry flask and stopper. Fill your pycnometer halfway with water, insert the stopper, then gently tap the sides to remove air bubbles to get the exact volume. Dry the sides and use the analytical balanceto weigh the entire pycnometer. Take a temperature reading of the water. Calculate the volume of water in the whole pycnometer flask using the known density of water from the CRC handbook. Make sure you're using the correct temperature and the known density value.

$$\frac{m_{oil}}{m_{water}} \times \rho_{water} = \rho_{oil}$$

The pycnometric method for determining density has several advantages, including high measurement accuracy (to 10-5 g/cm3), the ability to use small amounts of material (0.5 to 100 cm3), the small area of free surface of the liquid in the pycnometer (which virtually eliminates evaporation of the liquid and absorption of moisture from the air), and the separation of the thermostatic control and subsequent weighing operations.

Figure 3.5 Pycnometer filled with blue liquid

3.6 Pensky Martens Flash Point Tester

During testing, the Pensky-Martens Closed Cup Flash Point Tester detects the flash points of fuels, lubricating oils, liquids with suspended solids, and liquids that tend to form a surface film. It uses a closed cup method with high-speed stirring to determine the flash points of a wide range of goods.

The pensky martens closed cup tester are operated according to ASTM D93. In this research, procedure A from ASTM D93 is applied. Distillated fuels such as diesel, biodiesel blends, kerosene, heating oil, and turbine fuels are covered under Procedure A. It can also be used for fresh and used lubricating oils, as well as other homogenous petroleum liquids not covered by the other methods.

Referring to procedure A, the stirring device must be spun at 90 to 120rpm with the manual equipment, and the temperature must increase at a rate of 5 to 6°C (9 to 11°F) each minute. The ignition source should be provided at a temperature reading that is a multiple of 1°C or 2°F when the test specimen temperature reaches 23°C or 41°F below the predicted flash point for test specimens with an estimated flash point of 110°C or 230°F or below. When the test specimen temperature reaches 23 5°C or 41 9°F below the expected flash point for a test specimen with an expected flash point greater than 110°C or 230°F, the ignition source should be applied at each temperature increase of 2°C or 5°F when the test specimen temperature reaches 23 5°C or 41 9°F below the expected flash point. It is strongly recommended to dip the ignitor every 10°C throughout the test until the sample temperature reaches 28°C below the expected flash point if the expected flash point is above 130°C.

Figure 3.6 Pensky-Martens Closed Cup Flash Point Tester

CHAPTER 4

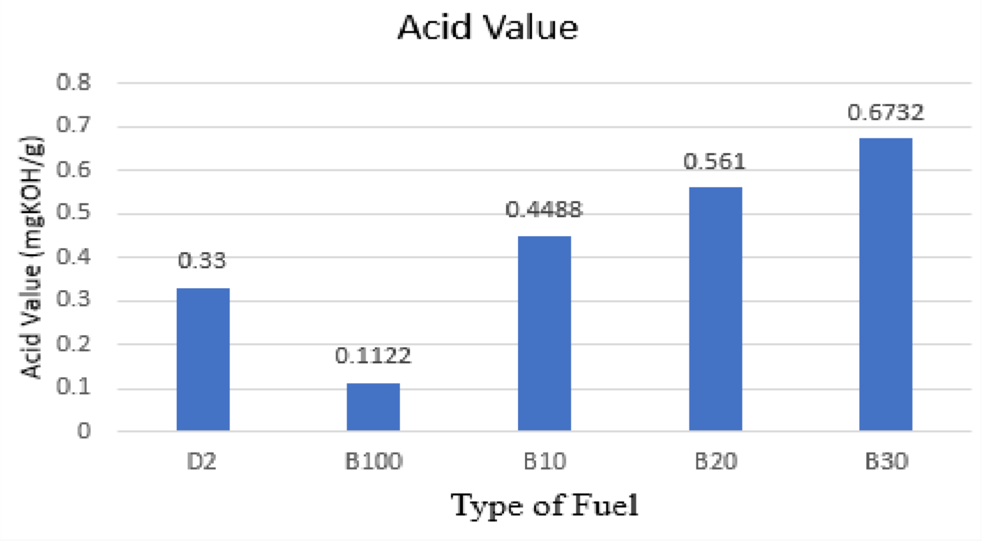
RESULTS AND DISCUSSION

4.1 Titration test

The titration test is conducted to find the acid value of the biodiesel blends which includes B10, B20, B30, B100, and D2 diesel. The reson to find the acid value is because of corrosion and engine deposits are linked to high fuel acidity, particularly in the fuel injectors. The amount of free fatty acids and mineral acids present in the sample is indicated by the acid number or acid value of edible oils or their equivalent esters. According to ASTM D-6751, the maximum acid value for pure biodiesel (B100) is 0.5 mgKOH/g. While for D2 diesel, there are no limits to the acid value.

Type of Fuel	Acid Value (mgKOH/g)
D2	0.33
B100	0.1122
B10	0.4488
B20	0.5610
B30	0.6732

Table 4.1 Acid value of Biodiesel Blends and D2 Diesel



Graph 4.1 Acid value of Biodiesel Blends and D2 Diesel

Based on the results, only B100 biodiesel and B10 biodiesel blend did pass the property specificatio based on ASTM D-6751, which the value is below 0.5mgKOH/g. The D2 diesel also passes its property specification based on ASTM D-975 which has no maximum value. The acid value of the B20 biodiesel dlend and B30 biodiesel blend only goes up higher as the biodiesel content goes up. These two biodiesel blend did not pass the ASTM D-6715 standards.

4.2 Pycnometer

The pycnometer method is used to find the density of the biodiesel blends which includes B10, B20, B30, B100, and D2 diesel. The reson to find the density is because of the spray momentum and equivalency ratio distribution are mostly affected by the fuel density. Aside from that, density is often used in a variety of biodiesel producing unit operations. Density values are also needed to construct reactors (the engine), distillation units, storage tanks, and pipes effectively.

Type of Fuel	Density (Kg/m^3)
D2	876
B100	844.08
B10	836.646
B20	838.450
B30	838.851

Table 4.2 Density of Biodiesel Blends and D2 Diesel

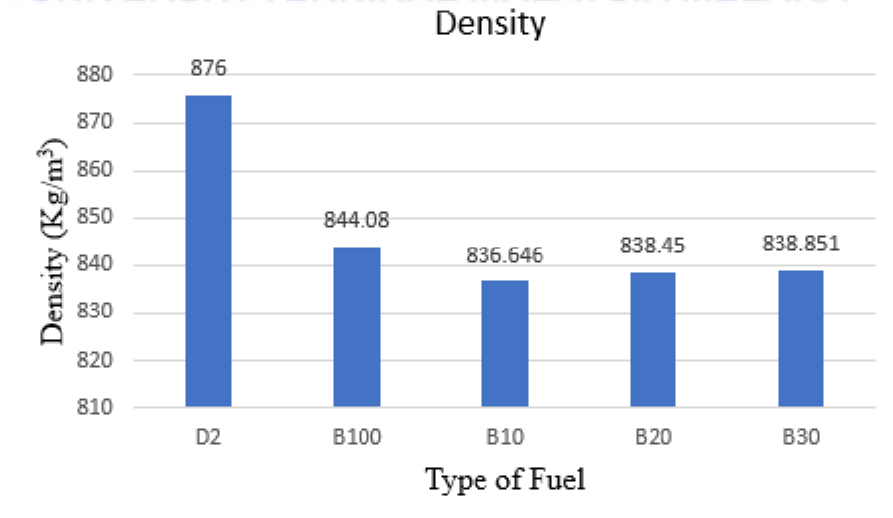


Table 4.2 Density of Biodiesel Blends and D2 Diesel

The density from all of the biodiesel blends pass the property specification stated on the ASTM D-6751 which is below 880 Kg/m^3. But the D2 diesel we used in this experiment did not pass the property specification of ASTM D-975, it is 16kg/m^3 higher than the allowed maximum density reading of 860kg/m^3. This may be caused by the different raw material used to produce it. This could be produced this way intentionally, because of the weather difference between countries.

4.3 Pensky Martens Flash Point Tester

The Pensky Martens flash point tester is used to find the flash point for biodiesel blends which includes B10, B20, B30, B100, and D2 diesel. The reson for finding the flash point is to determine the lowest ignitable temperature of the biodiesel blend. Because the air in a diesel engine's combustion chamber is compressed at a far higher rate than in a gasoline engine's combustion chamber. The air begins to heat up as it compresses, eventually reaching a temperature that ignites the fuel. So if the flash point of the biodiesel blends are not suitable, then the engine will not run in the way it should be.

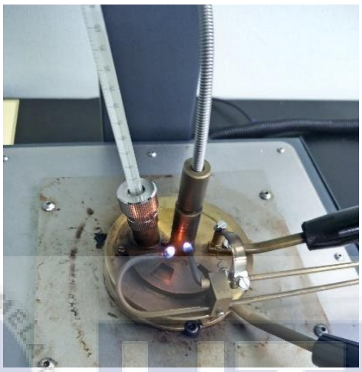
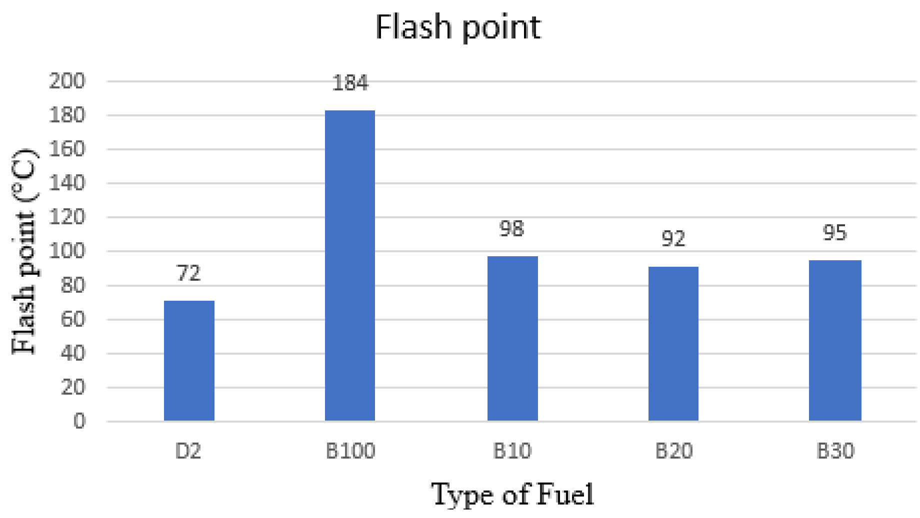


Figure 4.3 Pensky Martens flash point tester

Type of Fuel	Flash point (°C)
D2	72
B100	184
B10	98
B20	92
B30	95

Table 4.3 Flash point of Biodiesel Blends and D2 Diesel



Graph 4.3 Flash point of Biodiesel Blends and D2 Diesel

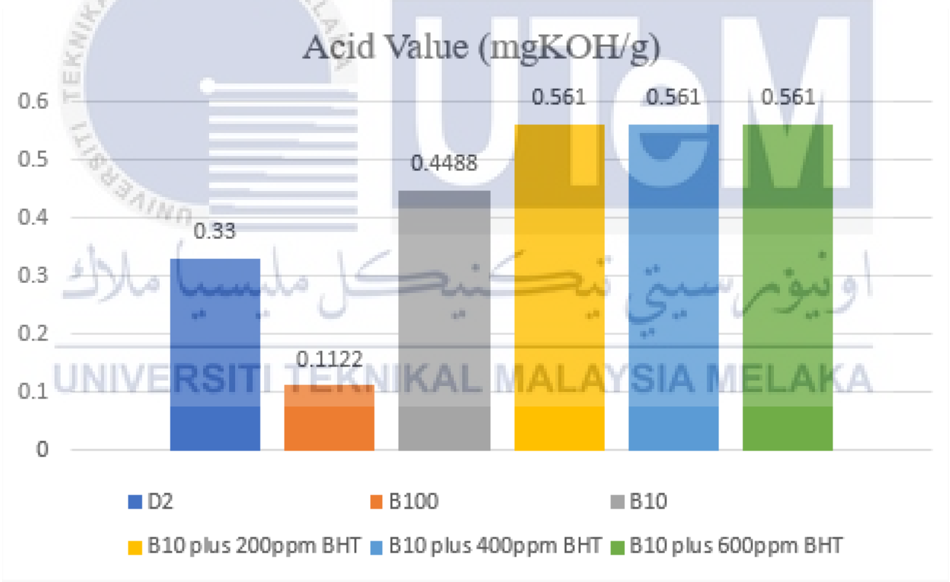
The flash point test turns out to have a very good result as all of the flash point for the biodiesel blends have passed the property specification stated in ASTM D-6751 which is below or equal to 130°C. But there are an error in the experiment for the B20 biodiesel blend which its flash point turns out lower than the flash point of B30 biodiesel blend. The flash point of B20 biodiesel blend shoud be between the flash point of B10 and B30 biodiesel blend, and that is between 98°C and 95°C.

4.4 Comparison of biodiesel blends after adding BHT

4.4.1 Acid value

Type of Fuel	Acid Value (mgKOH/g)
D2	0.33
B100	0.1122
B10	0.4488
B10 plus 200ppm BHT	0.561
B10 plus 400ppm BHT	0.561
B10 plus 600ppm BHT	0.561

Table 4.4.1 Acid value comparison after adding BHT



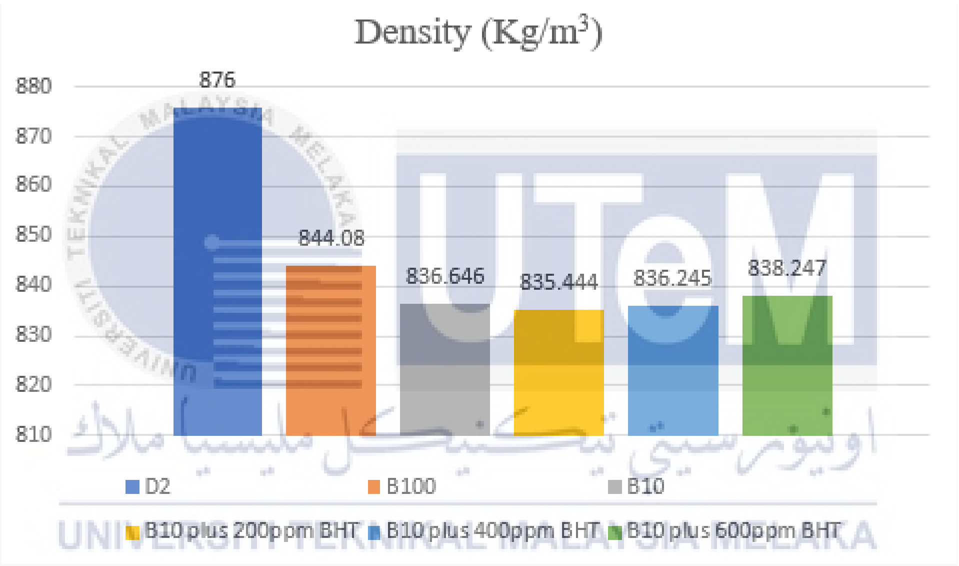
Graph 4.4.1 Acid value comparison after adding BHT

After adding the BHT into the B10 biodiesel blend, the acid value of the B10 biodiesel blend went up but it stabilized and kept at 0.561mgKOH/g. The adding of BHT did cause the acid value to rise but it increases the stability of the biodiesel blend. The increase of stability of the biodiesel blend can then ease the prediction of wear for the components used in the engine.

4.4.2 Density

Type of Fuel	Density (Kg/m^3)
D2	876
B100	844.08
B10	836.646
B10 plus 200ppm BHT	835.444
B10 plus 400ppm BHT	836.245
B10 plus 600ppm BHT	838.247

Table 4.4.2 Density comparison after adding BHT



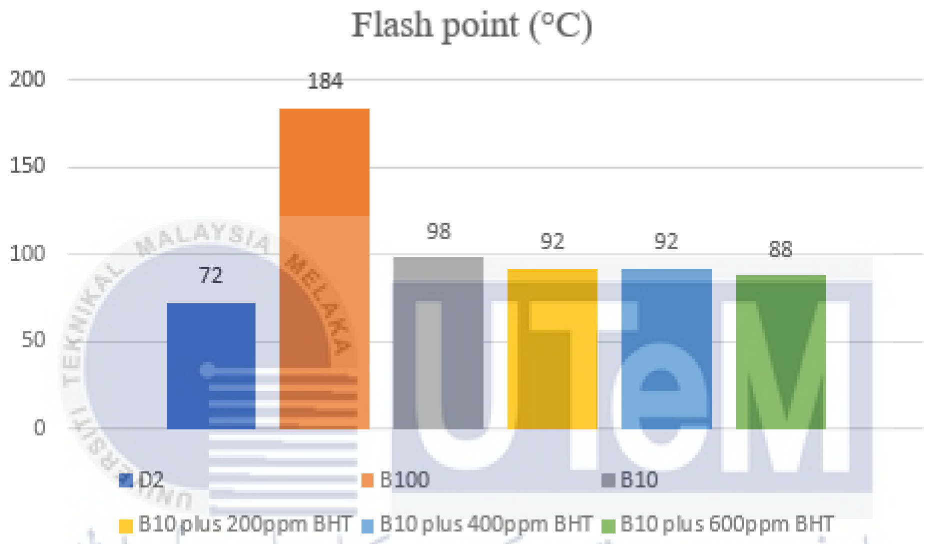
Graph 4.4.2 Density comparison after adding BHT

The BHT added first cause the density to drop when 200ppm is added to the B10 biodiesel blend. But when the BHT added to the B10 biodiesel blend increases to 400ppm and 600ppm, the density of the B10 biodiesel blend kept increasing. According to the data collected, only 200ppm and 400ppm of BHT are beneficial for the B10 biodiesel blend as the density of these two samples resulted on a lower density reading compared to the B10 biodiesel blend without BHT.

4.4.3 Flash point

Type of Fuel	Flash point (°C)
D2	72
B100	184
B10	98
B10 plus 200ppm BHT	92
B10 plus 400ppm BHT	92
B10 plus 600ppm BHT	88

Table 4.4.3 Flash point comparison after adding BHT



Graph 4.4.3 Flash point comparison after adding BHT

From the data collected, the BHT will decrease the temperature for the B10 biodiesel blend to reach its flash point. The BHT help decrease and stabilises the flash point for B10 biodiesel blend at 92°C, when 200ppm and 400ppm is added. It then starts to decrease again to 88°C when 600ppmis added to the B10 biodiesel blend, this can help to develop an engine when a lower flash point is needed at some colder places.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the acid value, density, and flash point of B10 biodiesel blend, B20 biodiesel blend, B30 biodiesel blend, B100, and D2 diesel have been succesfully found. The results are far from accurate and most of the result from the titration test which is used to find the acid value did not pass the properties standard stated in ASTM D-6751. The BHT added did cause the acid value to increase but it did helps to stabilize the acid value of B10 biodiesel blend. For the pycnometer method used to find the density of the biodiesel blends and D2 diesel, the results seem accurate and all of the biodiesel blends have met the properties specification stated in ASTM D-6751. However for the D2 diesel, it have failed to meet the properties standard in ASTM D-975. The BHT did well at decreasing the density at 200ppm and 400ppm but from 600ppm, the density goes over the density value of B10 Biodiesel blend. And finally for the Pensky Martens flah point test, the flash point of the biodiesel blends seems quite promising except for the B20 biodiesel blends as it did not fall between the flash point of B10 biodiesel blend and B30 biodiesel blend. In this case, the BHT performed well on decreasing the flash point of B10 biodiesel blend. We can conclude that, if BHT were to be added to B10 biodiesel blend, the amount of 200ppm would be the best as it outperformed the 400ppm and 600ppm.

5.2 Recommendations

More experiments should be conducted in the future in order to obtain a more accurate information on the biodiesel blends. Because of the lack of biodiesel blends, the number of experiments conducted in this research are far less than what should be done. As the results, the information gathered are not as accurate and correct as it should be.

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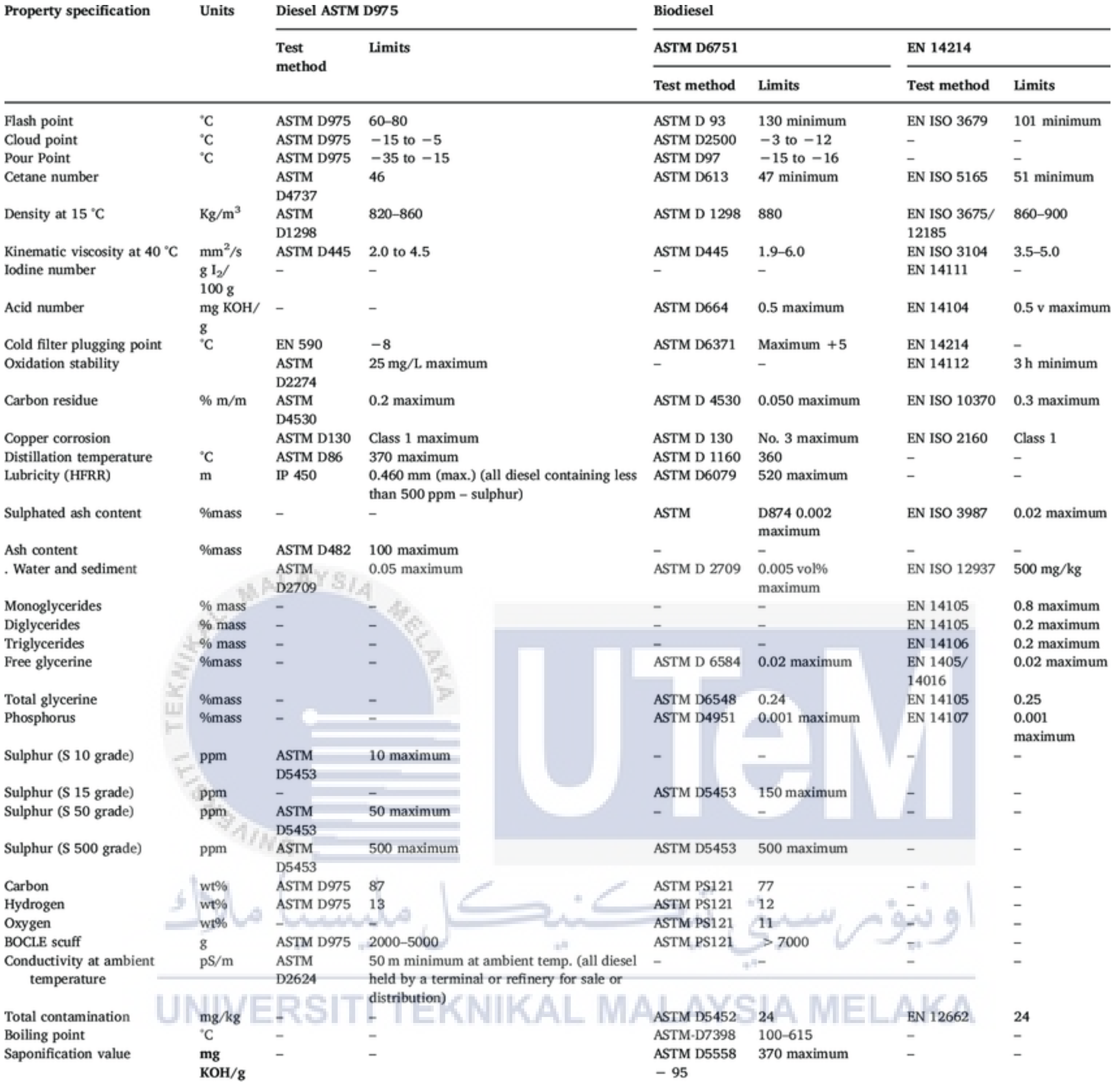
APPENDICES

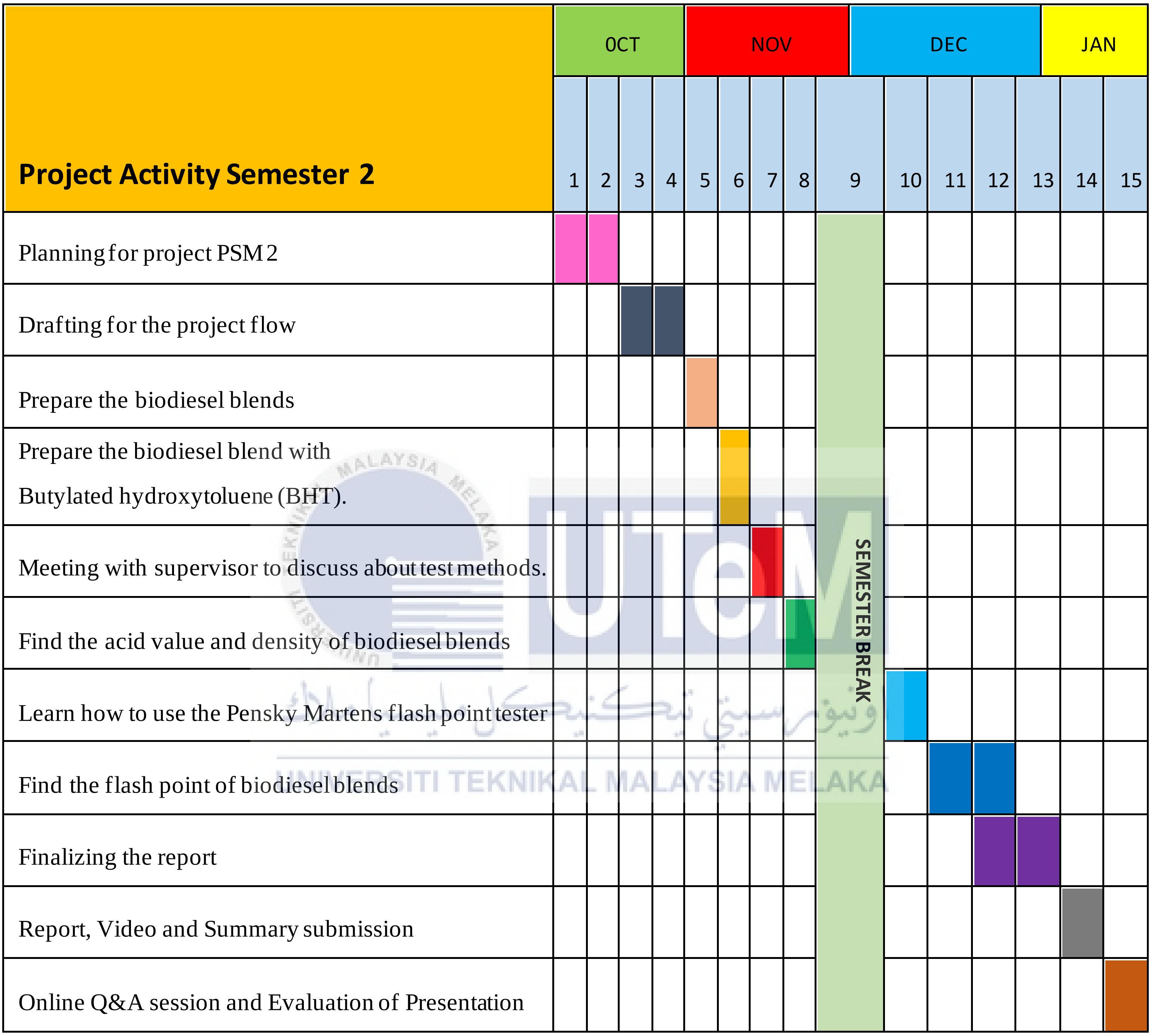


Property specification	Units	Diesel ASTM D975		Biodiesel			
				ASTM D6751		EN 14214	
		Test method	Limits	Test method	Limits	Test method	Limits
Flash point	°C	ASTM D975	60–80	ASTM D 93	130 minimum	EN ISO 3679	101 minimum
Cloud point	°C	ASTM D975	−15 to −5	ASTM D2500	−3 to −12	–	–
Pour Point	°C	ASTM D975	−35 to −15	ASTM D97	−15 to −16	–	–
Cetane number		ASTM D4737	46	ASTM D613	47 minimum	EN ISO 5165	51 minimum
Density at 15 °C	Kg/m^3	ASTM D1298	820–860	ASTM D 1298	880	EN ISO 3675/ 12185	860–900
Kinematic viscosity at 40 °C	mm^2/s	ASTM D445	2.0 to 4.5	ASTM D445	1.9–6.0	EN ISO 3104	3.5–5.0
Iodine number	$g\ I_2/100\ g$	–	–	–	–	EN 14111	–
Acid number	mg KOH/g	–	–	ASTM D664	0.5 maximum	EN 14104	0.5 v maximum
Cold filter plugging point	°C	EN 590	−8	ASTM D6371	Maximum +5	EN 14214	–
Oxidation stability		ASTM D2274	25 mg/L maximum	–	–	EN 14112	3 h minimum
Carbon residue	% m/m	ASTM D4530	0.2 maximum	ASTM D 4530	0.050 maximum	EN ISO 10370	0.3 maximum
Copper corrosion		ASTM D130	Class 1 maximum	ASTM D 130	No. 3 maximum	EN ISO 2160	Class 1
Distillation temperature	°C	ASTM D86	370 maximum	ASTM D 1160	360	–	–
Lubricity (HFRR)	m	IP 450	0.460 mm (max.) (all diesel containing less than 500 ppm – sulphur)	ASTM D6079	520 maximum	–	–
Sulphated ash content	%mass	–	–	ASTM	D874 0.002 maximum	EN ISO 3987	0.02 maximum
Ash content	%mass	ASTM D482	100 maximum	–	–	–	–
. Water and sediment		ASTM D2709	0.05 maximum	ASTM D 2709	0.005 vol% maximum	EN ISO 12937	500 mg/kg
Monoglycerides	% mass	–	–	–	–	EN 14105	0.8 maximum
Diglycerides	% mass	–	–	–	–	EN 14105	0.2 maximum
Triglycerides	% mass	–	–	–	–	EN 14106	0.2 maximum
Free glycerine	%mass	–	–	ASTM D 6584	0.02 maximum	EN 1405/ 14016	0.02 maximum
Total glycerine	%mass	–	–	ASTM D6548	0.24	EN 14105	0.25
Phosphorus	%mass	–	–	ASTM D4951	0.001 maximum	EN 14107	0.001 maximum
Sulphur (S 10 grade)	ppm	ASTM D5453	10 maximum	–	–	–	–
Sulphur (S 15 grade)	ppm	–	–	ASTM D5453	150 maximum	–	–
Sulphur (S 50 grade)	ppm	ASTM D5453	50 maximum	–	–	–	–
Sulphur (S 500 grade)	ppm	ASTM D5453	500 maximum	ASTM D5453	500 maximum	–	–
Carbon	wt%	ASTM D975	87	ASTM PS121	77	–	–
Hydrogen	wt%	ASTM D975	13	ASTM PS121	12	–	–
Oxygen	wt%	–	–	ASTM PS121	11	–	–
BOCLE scuff	g	ASTM D975	2000–5000	ASTM PS121	> 7000	–	–
Conductivity at ambient temperature	pS/m	ASTM D2624	50 m minimum at ambient temp. (all diesel held by a terminal or refinery for sale or distribution)	–	–	–	–
Total contamination	mg/kg	–	–	ASTM D5452	24	EN 12662	24
Boiling point	°C	–	–	ASTM-D7398	100–615	–	–
Saponification value	mg KOH/g	–	–	ASTM D5558 − 95	370 maximum	–	–

Appendix 1 Property specification and Test methods for Biodiesel and Diesel

Project Activity Semester 1	MARCH			APRIL				MAY					JUNE		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Planning	🟥	🟥							MID SEM BREAK						
Background research & Identify Problem Statement			🟥	🟥											
Define Objective & Scope					🟪	🟪	🟪								
Research & Literature Reviews						🟩	🟩	🟩		🟩					
Methodology & Survey											🟩	🟩	🟩		
Submission & Presentation of PSM 1														🟩	🟩

Appendix 2 Gantt chart of PSM 1



Project Activity Semester 2	0CT				NOV					DEC				JAN	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Planning for project PSM 2	■	■							SEMESTER BREAK						
Drafting for the project flow			■	■											
Prepare the biodiesel blends					■										
Prepare the biodiesel blend with Butylated hydroxytoluene (BHT).						■									
Meeting with supervisor to discuss about test methods.							■								
Find the acid value and density of biodiesel blends								■							
Learn how to use the Pensky Martens flash point tester										■					
Find the flash point of biodiesel blends											■	■			
Finalizing the report												■	■		
Report, Video and Summary submission														■	
Online Q&A session and Evaluation of Presentation															■

Appendix 3 Gantt chart of PSM 2

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