ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS

ENGINEERING

M.Sc. Thesis Paper

On

Production of Bio-Diesel from Neem oil and its Performance Analysis in four stroke Diesel Engine (Tank Engine)

By

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June , 2015

Candidate Declaration

I hereby declare that the work which is being presented in the design project entitled "Production of Bio-Diesel from Neem oil and its performance Analysis in four stroke Diesel Engine (Tank Engine)" in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive Engineering is an authentic record of my work carried out from September 1, 2014 to May 31, 2015 under the supervision of Ramesh Babu (Associate Professor), Department of Mechanical and Vehicle Engineering, Adama Science and Technology University, Ethiopia.

Fanosie Kebede _____ _____

Student's name Signature Date

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

Ramesh Babu (Associate Professor) _____ _____

Advisor Signature Date

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APPROVAL SHEET

Chairman, Board of examiners	**Signature**	**Date**
Internal Examiner	**Signature**	**Date**
External Examiner	**Signature**	**Date**
Advisor	**Signature**	**Date**

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1. INTRODUCTION

1.1 Background and justification

For more than two centuries, the world's energy supply has relied heavily on non renewable crude oil derived liquid fuels. The fractional distillate products of crude petroleum have widely used for transportation and different energy generation applications. But the crude petroleum is non-recoverable energy source, which is produced from left over fossils in the ground for more than billion years. So exploring new energy resources, such as biodiesel fuel, is of growing importance in recent years. Biodiesel is an alternative fuel made from renewable biological resources such as vegetable oils (both edible and non-edible oil) and animal fats.

Ethiopia imports its entire petroleum fuel requirement and the demand for petroleum fuel is rising rapidly due to a growing economy and expanding infrastructure from year to year. Moreover clean energy for current economic development is crucial to assure a sustainable development. Thus, looking for alternative sources of energy, bio-fuel is the most important one. Bio-fuel is derived from renewable biological resources and potentially inexhaustible source of energy for use in diesel engines.

Oil seed crops such as Neem, Jatropha carcus, palm seeds, soybean, canola, and sunflower are particularly useful for producing bio-diesel fuel. Nowadays, with the recent high and volatile prices of oil, different countries are being forced to develop innovative policies to mitigate the impact of these high prices on their economies. The most effective policy in this respect is the diversification of energy supply sources in the transport sector, Biodiesel appear to offer the best opportunities.

The development of Biodiesel for the country can bring many benefits that includes.

- Increased energy supply security through diversification and progressive substitution of oil.
- Reduced national oil importation.
- Increased agricultural activity, bringing in economical benefit to the farmers making use of non arable lands.
- Reduced emission of pollutants, including greenhouse gases, thus providing both local and global environmental benefits.

Neem seeds have a great amount of oil content but the people of Ethiopia are not using it but the people of Deredawa uses the leaves as medicine to cure there stomach ache, for shelter, for their domestic animal food etc…that is why they call it **(kenin zaf).**

Neem (kenin zaf) plants are abundantly growing in Ethiopia especially in Deredawa and around Awash. But no one has given attention to take care of neem plants in our country even though they are very rich energy potentials especially for the production of bio-diesel and to fight against crop pests and diseases and for medicinal application. Therefore, the energy potential of this neem seed will be investigated for its performance and emission characteristics as a diesel fuel in laboratory scale.

1.2 Statement of problem

The government of the nation believes that the policy is appropriate and reliable to bring over all fast economic development in the country. Ethiopia is a fast growing country and they require large amount of energy. Energy crises can be caused due to unbalanced demand-supply ratio of non-renewable energy sources become an obstacle in the development of country. And also the primary concern today is environmental pollution. Moreover, reliable access to transport fuels concerns all countries. But for oil importing countries like Ethiopia; it becomes even more critical development and security issue.

Therefore, Ethiopia should exploit all possible alternatives to mitigate its dependence on petroleum imports. Diesel fuel is the most important transport fuel in Ethiopia as all the public transport uses it. For this critical problem; alternative renewable sources are constantly on the search of. Most people of Ethiopia are unable to satisfy their house hold energy requirement with modern energy sources. In rural areas, they use biomass only for cooking, baking, and heating. This in turn leads to erosion and desertification. On the other hand, petroleum products which are used mainly in the urban house hold are entirely imported commodity.

Demand for these products is rising rapidly due to scarcity of fuel and the change of life style of the people. This will be accompanied by the growth in the import bill, because of the rising petroleum prices. Reduction of petroleum import bills by practical substitution of bio-diesel will enable the government to allocate the foreign exchange to other expenditures. Therefore, this laboratory scale study helps for the development of clean, new renewable energy and

locally available, particularly bio-diesel extraction from Neem seed as an alternative energy solution to petroleum oil in response to the rise in oil price which has adverse effects on the economy of the country. By extracting bio-diesel from Neem seeds in large scale,

- Ethiopia may save its foreign expenditure,
- create job opportunities,
- increase its economic growth and participate to create clean environment.

1.3 Objectives of the study

1.3.1 General objective

The general objective of this research paper is to evaluate the performance of Biodiesel produced from neem seeds in a four stroke cycle diesel engine.

1.3.2 Specific objectives

Specific objective of the study are as follows

- To produce bio-diesel from Neem seeds using transesterification process.
- To measure the physio-chemical properties of biodiesel produced from Neem seeds and its blends.
- To evaluate the performance of biodiesel in four stroke diesel engine.
- To compare the performance of Neem biodiesel with petro diesel

1.4 Significance of the study

- Production of Biodiesel from Neem seed can help close the trade gap by substitution imported petroleum.
- To use Biodiesel as a complete substitution or a blend with petroleum with appropriate mixing ratio to propel diesel engine or tank engine with a better performance.
- To reduce emission pollutants including greenhouse gasses, thus producing environmental benefits.
- To reduce petroleum import bills and secure oil fuel supply.

Therefore, this study helps for the development of clean, new renewable energy and locally available, particularly bio-diesel extraction from Neem seed as an alternative energy solution to

petroleum oil in response to the rise in oil price which has adverse effects on the economy of the country. By extracting oil from Neem seeds in large scale, Ethiopia may save its foreign expenditure, create job opportunities, establish local industrial base, increase its economic growth and participate to create clean environment.

2. LITERATURE REVIEW

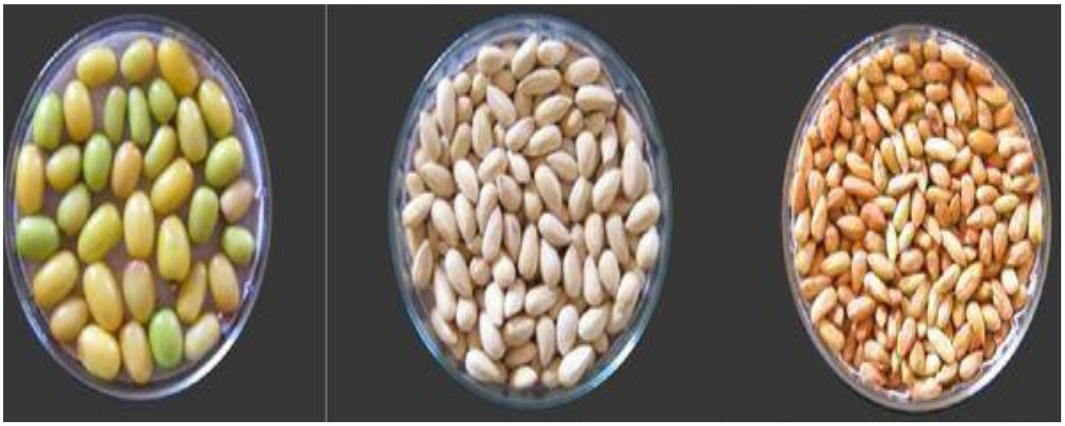
What is Neem?

Neem is a tree is abundantly grown in Ehiopiaa especially in Deredawa, Awash and around. The Neem grows on almost all types of soils including clayey, saline and alkaline conditions. Neem seed obtained from this tree are collected, de-pulped, sun dried and crushed for oil extraction. The seeds have 40% oil which has high potential for the production of biodiesel. Neem oil is generally light to dark brown, bitter and has a rather strong odour that is said to combine the odours of peanut and garlic. It comprises mainly of triglycerides and large amounts of triterpenoid compounds, which are responsible for the bitter taste. It is hydrophobic in nature and in order to emulsify it in water for application purposes, it has to be formulated with appropriate surfactants.

Neem oil also contains steroids (campesterol, beta-sitosterol, stigma sterol) and a plethora of triterpenoids of which Azadirachtin is the most widely studied. This study is intended to consider aspects related to the feasibility of the production of biodiesel from Neem seed oil in an attempt to produce biodiesel using the abundantly grown tree naturally as the use of vegetable oils for engine fuels seems insignificant at present day scenario. Neem oil will become a potential supplier of Biodiesel in future.

Biodiesel is a mono alkyl ester (methyl or ethyl ester) of long chain fatty acids derived from renewable lipid of Neem oil. Biodiesel thus obtained can be used in any compression ignition (diesel) engines without the need of modification and is therefore a good substitute for diesel fuel. The first documented commercial production of rape seed oil methyl esters is reported to be in 1988. It possesses several distinct advantages over petro-diesel in following safety, biodegradability and environmental aspects.

Figure 1: Picture of Neem tree



Neem seeds Neem Kernel Neem Kernel after drying

Figure 2: Neem seeds

2.1 Introduction to biodiesel

Biodiesel derived from vegetable oil attracts attention as a promising one to be substituted for conventional diesel fuels. Biodiesel has been promoted as a form of biomass that can be used as a renewable energy source to reduce net emissions of carbon dioxide into the atmosphere. Therefore, biodiesel is seen as a way to decrease the impact of the greenhouse effect and as a way of diversifying energy supplies to assist national energy security plans. According to the US Standard Specification for Biodiesel (ASTM 6751), Biodiesel is defined as a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats. In this context, it can be used in diesel engines and heating systems. Biodiesel is an ecologically friendly fuel which has a lower emission than petroleum fuels and has less green house gases emission from flue gases of engines. Therefore the scarcity of conventional fossil fuel, the growing emissions of combustion and the rising price will make alternative energy more attractive.

Petroleum based fuels are limited reserves concentrated in certain regions of the world. These sources are on the verge of reaching their peak production. The scarcity of known reserves will make renewable energy sources more attractive. In addition, Biodiesel is safer to handle (flash point above 170^0C contains no or little sulphur or carcinogenic poly aromatic components and decreases soot emissions which is very advantageous in environmentally sensitive area.

In general biodiesel has many advantages:

- Safe for use in all conventional diesel engines
- Offers the same performance and engine durability as petroleum diesel fuel
- Non-flammable and nontoxic REF
- Reduces tailpipe emissions, visible smoke and noxious fumes and odors.

Biodiesel is pure or 100% Biodiesel fuel it is referred to as B100 or “neat” fuel. **Biodiesel blend** is pure Biodiesel blended with petrol diesel. Biodiesel blends are referred to as **Bxx.** The **xx** indicates the amount of biodiesel in the blend. Biodiesel/diesel mixtures have ranged from 5/95% (B2), 20/80% (B20) up to 100% (B100). B80 blend is 80% biodiesel and 20% petrol diesel by volume.

Biodiesel can be produced from a variety of renewable lipid sources including neem, jatropha carcus, soybeans, canola, palm, peanut, cotton and sunflower oils. However, some of these oil

sources are commodities whose prices are strongly dependent on the international market. Moreover, the food industry imposes a direct competition for this feedstock and this may be critical for a world whose population is increasing exponentially. For these and other reasons, non-edible oil sources are preferable for Biodiesel production, particularly those requiring low agronomic demand for cultivation, a reasonable plant cycle, favorable geographic adaptability, high oil content and a low cost for cultivation and harvesting.

2.2 Biodiesel as an alternative fuel in diesel engines

Biodiesel is amber-yellow liquid with a viscosity similar to that of petro diesel which is non flammable, non explosive in contrast to petro diesel with a flash point 173.8^0C as compared to 71^oC for petrol diesel. Unlike to petrol it is also degradable by anaerobic bacteria, biodiesel is biodegradable and non toxic and it significantly reduces toxic and other emissions when burned as a fuel. Currently, Biodiesel is more expensive to produce than petrol diesel, which appears to be the primary factor in preventing its more widespread use. Currently worldwide production of vegetable oil and animal fats is not enough to replace liquid fossil fuel use (maximum replacement percentage; 20 to25%).

The advantages of biodiesel as diesel fuel are its portability, renewability, higher combustion efficiency, ready availability, lower Sulphur and aromatic contents higher cetane number and higher biodegradability REF. The main advantage of Biodiesel includes its domestic origins which will help reduce a country's dependency on imported petroleum, its biodegradability, higher flash point, and inherent lubricity in the neat form.

The major disadvantages of Biodiesel are its higher viscosity, lower energy content, higher cloud point, and pour point, higher nitrogen oxide (NOx) emissions, lower engine speed and power, injector coking, engine compatibility, high price and greater engine wear.

The technical disadvantages of Biodiesel/fossil diesel blends include problems with fuel freezing in cold weather, reduced energy density, and degradation of fuel under storage for prolonged periods. The other problem is encountered when blends are first introduced into equipment that has a long history of pure hydrocarbon usage. Hydrocarbon fuels typically form a layer of deposits on the inside of tanks, hoses, etc.

Biodiesel blends loosen these deposits, causing them to block fuel filters. However, this is a minor problem, easily remedied by proper filter maintenance during the period following introduction of the biodiesel blend. REF

The advantages of biodiesel in this respect are that it is a derivative of natural products. As demand rises, the production of the required agricultural products can be increased to compensate. Biodiesel is technologically feasible alternative to fossil diesel, but n owadays biodiesel costs are more than fossil fuel. As far as actual fuel costs are concerned, the cost of biodiesel is currently comparable to that of gasoline. Biodiesel will be a reasonably available engine fuel in the near future.

2.3 Production of biodiesel

2.3.1 Transesterification process

Oils from plants and animal fats are very difficult to use as engine fuels , because they contain free fatty acids, phospholipids, sterols, water, and odorants and other impurities. Because of these, the oil cannot be used as fuel for compression ignition engines directly. To overcome these problems the oil requires slight modification by a chemical reaction called transesterification, especially to reduce the viscosity of the oils derived from vegetable and animal fats.

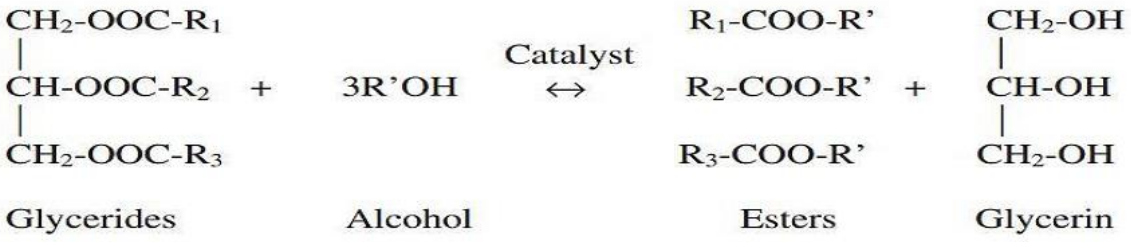
Transesterification is defined as a chemical process used to produce a fatty acid methyl ester or ethyl ester and glycerol a byproduct from the reaction of vegetable oils or animal fats with short chain alcohol in the presence of catalyst.

Transesterification is the key and foremost important step to produce the cleaner and environmentally friendly fuel from vegetable oils and animal fats. Biodiesel is the monoalkyl esters of long chain fatty acids derived from renewable feed stocks, such as vegetable oil or animal fats, for use in compression ignition engine.

Biodiesel, which is considered as a possible substitute of conventional diesel fuel is commonly, composed of fatty acid methyl esters that can be prepared from triglycerides in vegetable oils by transesterification with methanol or ethanol basic catalysts. The resulting biodiesel is quite similar to conventional diesel fuel in its main physical characteristics the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis is known as alcoholysis or transesterification except that alcohol is used instead of water.

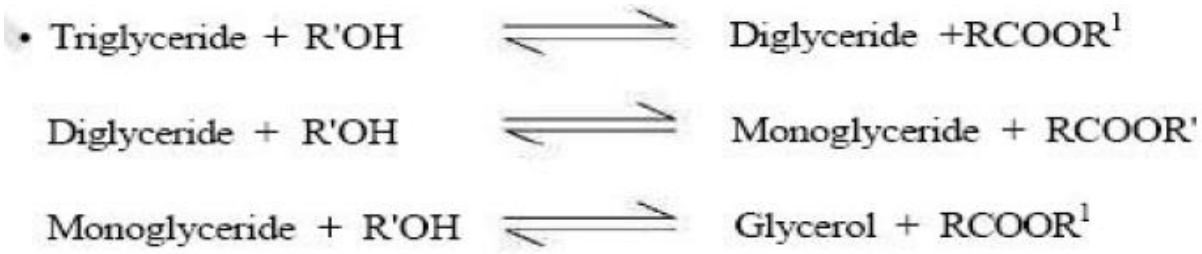
This process has been widely used to reduce the high viscosity of triglycerides.

The transesterification process can be done in a number of ways such as using an alkali catalyst, acid catalyst, biocatalyst or heterogeneous catalyst. The general reaction is shown as below:



Transesterification reaction of vegetable oil with alcohol to esters and glycerol

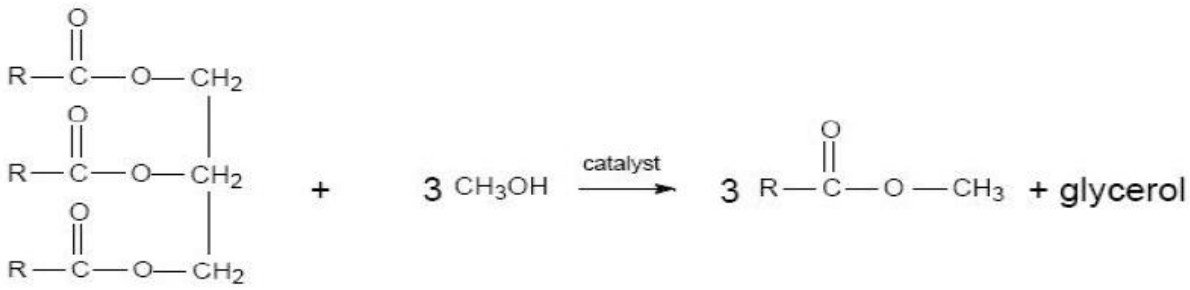
Equation 1



In the reaction shown above in equation1, triglycerides, as the main components of vegetable oils, react with an alcohol to produce fatty acid mono-alkyl esters and glycerol. Alcohols are primary and secondary monohydric aliphatic alcohols having 1-8 carbon atoms. Among the alcohols that can be used in the transesterification process are methanol, ethanol, propanol and butanol.

Methanol and ethanol are used most frequently, especially methanol because of its low cost and its physical and chemical advantages (polar and shortest chain alcohol). It can quickly react with triglycerides and NaOH and KOH are easily soluble in it. This reaction consists of three consecutive reversible reactions with intermediate formation of diglycerides and monoglycerides which are dependent on the reaction time, temperature and concentration of catalysts. After the reaction, the glycerol is separated by settling or centrifuging and the layer obtained is purified to be used in its traditional applications (the pharmaceutical, cosmetics and food industries).

The biodiesel phase is also purified before being used as diesel fuel. The high viscosity component, glycerol, is removed and hence the product has low viscosity like the fossil fuels. The mixture of these mono-alkylesters can hence be used as a substitute for fossil fuels. After transesterification of triglycerides; the products are a mixture of esters, glycerol, alcohol, catalyst and tri-, di- and monoglycerides. Obtaining pure esters was not easy, since there were impurities in the esters, such as di- and monoglycerides, hence recovery of the traces of alcohol and glycerols are necessary before it is used as a biodiesel.



R is typically 16 or 18 carbons and may contain one to three carbon-carbon double bonds.

Transesterification reaction Equation 2

There are four types of transesterification processes, namely: basic, acidic, heterogeneous and enzymatic.

Transesterification using acidic catalyst

This technique uses a strong acid such as sulfuric acid to catalyze the esterification of the FFA and the transesterification of the triglycerides. The reaction does not produce soaps because no alkali metals are present. The esterification reaction of the FFA to alcohol esters is relatively fast, proceeding substantially to completion in one hour at 60ºC. However, the transesterification of the triglycerides is very slow, taking several days to complete.

Transesterification using basic catalyst

In the basic or alkali process sodium hydroxide (NaOH) or potassium hydroxide (KOH) is used as a catalyst along with methanol or ethanol. Initially, during the process, alcoxy is formed by reaction of the catalyst with alcohol and the alcoxy is then reacted with any vegetable oil to form biodiesel and glycerol.

Glycerol being denser settles at the bottom and biodiesel can be decanted. This process is the most efficient and least corrosive of all the processes and the reaction rate is reasonably high even at a low temperature of 60 to 80^{o}C. There may be risk of free acid or water contamination and soap formation which is likely to take place which makes the separation process.

Most studies of the basic-catalyzed transesterification of vegetable oils involve the calculations of the triglyceride conversion rate, the changes in product composition during reaction or some of the quality parameters of biodiesel.

All of these aspects are related to the biodiesel purity, which means the methyl ester concentration in the biodiesel phase. Even though the biodiesel yield after the post-treatment stage is another relevant aspect of the process, it is considered less in the literature.

The biodiesel yield could decrease due to the previously mentioned undesirable side reactions like triglyceride saponification and free fatty acid neutralization and also to dissolution of the methyl ester in the glycerol phase. For an alkali-catalyzed transesterification, the glycerides and alcohol must be substantially anhydrous. Because water makes the reaction partially change to saponification, which produces soap. The soap lowers the yield of esters and renders the separation of ester and glycerol and the water washing difficult. Low free fatty acid content in triglycerides is required for alkali-catalyzed transesterification.

Transesterification using heterogeneous catalyst

Heterogeneous catalysts such as amorphous zirconia, titanium-, aluminum-, and potassium doped zirconias have also become popular for catalyzing the transesterification of vegetable oils. It has been reported that the conversion to methyl ester reaches 87% with the potassium loaded alumina catalyst, when a mixture with a molar ratio of methanol to oil of 15:1 is refluxed for a reaction time 7h. Besides these, there have been several other reports on heterogeneous catalysts. However, the catalytic activities of most of them are not much greater than that of a homogeneous catalyst such as KOH. Furthermore, there is little information regarding their catalytic durability. Research is still in progress in order to solve the problem encountered in this process such as exhaustion of catalyst and to achieve higher conversion.

Of all the methods mentioned above for production of biodiesel, only the alkali process is carried out in an industrial scale. It is cost effective and highly efficient. However, problems arise in the downstream operations including separation of catalyst and un reacted methanol from biodiesel. The removal of the catalyst involves many complications and biodiesel requires

repeated washing for attaining the necessary purity. The production of biodiesel using a biocatalyst eliminates the disadvantages of the alkali process by producing product of very high purity with less or no downstream operations also patented this method of production of biodiesel using a biocatalyst. But the process has not yet been implemented in an industrial scale due to certain constraints like enzyme inhibition by methanol, exhaustion of enzyme activity and high cost of enzymes.

2.3.2 Factors affecting transesterification process

The mechanism and kinetics

Transesterification consists of a number of consecutive, reversible reactions.

The triglyceride is converted stepwise to diglyceride, monoglyceride and finally glycerol.

A mole of ester is liberated at each step. The reactions are reversible, although the equilibrium lies towards the production of fatty acid esters and glycerol.

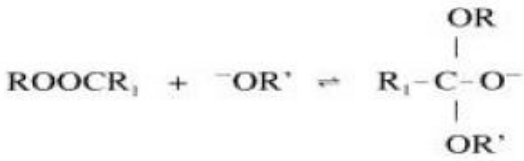
The reaction mechanism for alkali-catalyzed transesterification was formulated as three steps. The first step is an attack on the carbonyl carbon atom of the triglyceride molecule by the anion of the alcohol (methoxide ion) to form a tetrahedral intermediate. In the second step, the tetrahedral intermediate reacts with an alcohol (methanol) to regenerate the anion of the alcohol (methoxide ion). In the last step, rearrangement of the tetrahedral intermediate results in the formation of a fatty acid ester and a diglyceride. When NaOH, KOH, $K2CO_3$ or other similar catalysts were mixed with alcohol, the actual catalyst, alkoxide group is formed. A small amount of water, generated in the reaction, may cause soap formation during transesterification.

The mechanism of alkali-catalyzed transesterification is shown below

Pre-step: $OH^- + R'OH \rightleftharpoons R'O^- + H_2O$ or

$NaOR' \rightleftharpoons R'O^- + Na^+$

Step1.



Step 2.

Step 3.

Where R-OH diglyceride, R_1 long chain alkyl group, and R'short alkyl group

The mechanism of alkali-catalyzed transesterification of triglycerides with alcohol

Equation3

The effects of moisture and free fatty acids

The effects of moisture (water) and free fatty acids as Wright noted that the starting materials used for alkali-catalyzed transesterification of glycerides must meet certain specifications. The glyceride should have an acid value less than1and all materials should be substantially anhydrous. If the acid value was greater than 1, more NaOH was required to neutralize the free fatty acids. Water also caused soap formation, which consumed the catalyst and reduced catalyst efficiency. The resulting soaps caused an increase in viscosity, formation of gels and made the separation of glycerol difficult and therefore, water content should be less than 0.3%. Bradshaw etaland Feuge etal also stressed the importance of oils being dry and free (<0.5%) of free fatty acids.

The effect of molar ratio

One of the most important variables affecting the yield of ester is the molar ratio of alcohol to triglyceride. The stoichiometric ratio for transesterification requires three moles of alcohol and one mole of glyceride to yield three moles of fatty acid ester and one mole of glycerol. The molar ratio is associated with the type of catalyst used. An acid catalyzed reaction needed a 30:1 ratio of NaOH to soybean oil, while an alkali-catalyzed reaction required only a 6:1 ratio to achieve the same ester yield for a given reaction time Bradshaw stated that the practical range of molar ratio was from 3.3 to 5.25:1 methanol to vegetable oil. The ratio of 4.8:1 was used in some examples, with a yield of 97-98%, depending upon the quality of the oils. If a three step transesterification process was used, the ratio was reduced to 3.3:1. Methanol present in amounts of above 1.75 equivalents tended to prevent the gravity separation of the glycerol, thus adding more cost to the process.

Higher molar ratios result in greater ester conversion in a shorter time. In the ethanolysis of peanut oil, a 6:1 molar ratio liberated significantly more glycerine than did a 3:1 molar ratio. Rapeseed oil was methanolyzed using 1% NaOH or KOH. They found that the molar ratio of 6:1 of methanol to oil gave the best conversion. When a large amount of free fatty acids was present in the oil, a molar ratio as high as 15:1 was needed under acid catalysis.

Freedman studied the effect of molar ratio (from 1:1 to 6:1) on ester conversion with vegetable oils. Soybean, sunflower, peanut and cotton seed oils behaved similarly and achieved highest conversions (93-98%) at a 6:1 molar ratio. Tanaka in his novel two-step transesterification of oils and fats such as tallow, coconut oil and palm oil, used 6:1- 30:1 molar ratios with alkali catalysis to achieve a conversion of 99.5%. A molar ratio of 6:1 was used for beef tallow transesterification with methanol.

The effect of catalyst

Alkali-catalyzed transesterification is much faster than acid-catalyzed. However if a glyceride has a higher free fatty acid content and more water, acid-catalyzed transesterification is suitable. The acids could be sulfuric acid, phosphoric acid, hydrochloric acid or organic sulfonic acid.

Alkalis include sodium hydroxide, sodium methoxide, potassium hydroxide, potassium methoxide, sodium amide, sodium hydride, and potassium amide and potassium hydride. Sodium methoxide was more effective than sodium hydroxide because of the hydroxide group

is responsible for the formation of soaps by the side-reaction of saponification of the triglycerides and they contain only a minor amount of the hydroxide group as impurity and due to the assumption that a small amount of water was produced upon mixing NaOH. Sodium hydroxide was also chosen to catalyze the transesterification because it is cheaper.

The effect of reaction time

The conversion rate increases with reaction time. Freedman transesterified peanut, cottonseed, sunflower and soybean oils under the condition of methanol to oil ratio of 6:1, 0.5% sodium methoxide catalyst and 60°C. An approximate yield of 80% was observed after 1 min for soybean and sunflower oils. After 1 h, the conversions were almost the same for all four oils (93-98%). The effect of reaction time on transesterification of beef tallow with methanol was discussed here. The reaction was very slow during the first minute due to the mixing and dispersion of methanol into beef tallow. From one to five min, the reaction proceeded very fast. The apparent yield of beef tallow methyl esters surged from 1 to 38. The production of beef tallow slowed down and reached the maximum value at about 15 min. The di- and monoglycerides increased at the beginning and then decreased. At the end, the amount of monoglycerides was higher than that of diglycerides

The effect of reaction temperature

Transesterification can occur at different temperatures, depending on the oil used. In methanolysis of castor oil to methyl ricinoleate, the reaction proceeded most satisfactorily at 20-35°C with a molar ratio of 6:1-12:1 and 0.005-0.35% (by weight of oil) of NaOH catalyst. For the transesterification of refined soybean oil with methanol (6:1) using 1% NaOH, three different temperatures were used. After 0.1 h, ester yields were 94, 87 and 64% for 60, 45 and 32°C, respectively. After 1h, ester formation was identical for the 60 and 45°C runs and only slightly lower for the 32°C run. Temperature clearly influenced the reaction rate and yield of esters.

2.4 Parameters which define the fuel quality of biodiesel

Petroleum derived diesel fuels, which used in CI engines are designed to satisfy the performance requirements of the CI engine system. Accordingly biodiesel produced from different feed stokes should satisfy the requirement. The suitability of biodiesel can be

influenced by contaminants arising from production or other sources, and the nature of the fuel components ultimately determines the fuel properties. The properties includeds,

2.4.1 Cetane Number

The cetane number of a fuel is a measure of how efficiently the fuel auto-ignites on injection and also indicates the efficiency of combustion or is a measure of the self-ignition quality of the fuel. Higher Cetane numbers indicate shorter times between the injection of the fuel and its ignition. Higher numbers have been associated with reduced engine roughness and with lower starting temperatures for engines. No.2 diesel fuel usually has a cetane rating between 45 and 50 while vegetable oil is 35 to 45. Biodiesel is usually 50 to 60. The ignition quality affects engine performance, cold starting, warm up and engine combustion roughness.

Cetane rating is related to the volatility of the fuel where more volatile fuels have higher ratings. A high cetane fuel also may lead to incomplete combustion and smoke if the fuel ignites too soon by not allowing enough time for the fuel to mix with air for complete combustion. Fuels with low Cetane numbers will result in difficult starting, noise and exhaust smoke. In general, diesel engines will operate better on fuels with Cetane Numbers above 50.

Cetane numbers measure the ignition of diesel much like octane numbers measure the ignition of gasoline. These numbers represent the measure of a fuel is willingness to ignite.

Biodiesel has a higher cetane number than that of diesel, largely because of its higher oxygen content. It is important to note that biodiesel cetane number can vary widely, based on differences in fatty acid composition of the feedstock oil and the saturation level of the fatty acids.

2.4.2 Acid value

The acid value measures the amount of un reacted acids remaining in the finished fuel, and is also an indicator of oxidized fuel. For biodiesel, the acid number is an indicator of the quality of the product. Specifically, it detects the presence of any UN reacted fatty acids still in the fuel, or of any acids that were used in processing. This is also an indication of the condition of the stability of the fuel, because the acid number increases as the fuel ages. Acid number is a measure of acids in the fuel. These acids emanate from two sources: acids utilized in the production of the biodiesel that are not completely removed in the production process; and degradation by oxidation. For biodiesel blends the acid number will change as a result of the

normal oxidation process over time. Once purchased, biodiesel fuel blends that will not be utilized immediately should be monitored for changes in acid number as an indicator of fuel degradation.

2.4.3 Cloud Point

The temperature at which oil starts to solidify is known as the cloud point. While operating an engine at temperatures below oil is cloud point, heating will be necessary in order to avoid waxing of the fuel. Small crystals of fuel begin to form in the liquid causing haziness as the sample is cooled. It is an indicator of the utility of petroleum oil for some applications. In the case of biodiesel, the haze is made up of crystallized fuel molecules; specifically crystallized stearic and/or palmatic methyl esters.

Using a product below its cloud point may reduce the lubricating properties, and may plug filters. For biodiesel, the settled material may not cause lubrication problems, but the remaining liquid may have lower properties relative to the fully mixed fuel. The pour point and cloud point are both higher for biodiesel fuel than for Gasoline-based diesel, indicating that biodiesel will tend to gel at higher temperatures than diesel, causing engine problems.

2.4.4 Viscosity

The term viscosity refers to the thickness of the oil (flow properties), and is determined by measuring the amount of time taken for a given measure of oil to pass through an orifice of a specified size. Viscosity affects injector lubrication and fuel atomization. Fuels with low viscosity may not provide sufficient lubrication for the precision fit of fuel injection pumps, resulting in leakage or increased wear. Fuel atomization is also affected by fuel viscosity. Diesel fuels with high viscosity tend to form larger droplets on injection which can cause poor combustion, increased exhaust smoke and emissions. The viscosity of biodiesel and biodiesel blends also increases more rapidly than diesel as temperature is decreased. Certain impurities also tend to significantly increase the viscosity of Biodiesel.

2.4.5 Calorific Value or Heat of Combustion

Heating Value or Heat of Combustion is the amount of heating energy released by the combustion of a unit value of fuels. One of the most important determinants of heating value is moisture content. Air-dried biomass typically has about 15-20% moisture, whereas the moisture content for oven-dried biomass is negligible. Moisture content in coals varies in the

range 2-30%. However, the bulk density (and hence energy density) of most biomass feed stocks is generally low, even after densification between about 10 and 40% of the bulk density of most fossil fuels. Liquid bio fuels however have bulk densities comparable to those for fossil fuels. The energy content of biodiesel and diesel is 30,933 and 34,685 BTU/L respectively. A "BTU" stands for British Thermal Unit which is defined as the energy required to raise the temperature of water one degree Fahrenheit Fuels with a high heat of combustion will usually produce more power per pound of fuel than fuels with lower energy. Gross heat of combustion increases with chain length.

2.4.6 Pouring Point

Melt or pour point refers to the temperature at which the oil in solid form starts to melt or pour. In cases where the temperatures fall below the melt point, the entire fuel system including all fuel lines and fuel tank will need to be heated.

2.4.7 Flash Point (FP)

The flash point temperature of diesel fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source. Flash point varies inversely with the fuel volatility. Minimum flash point temperatures are required for proper safety and handling of diesel fuel. Biodiesel and diesel have a common boiling point, but biodiesel has a higher flash point because biodiesel has a high number of FAMEs which are generally not volatile. Thus, biodiesel is safer to handle at higher temperatures than diesel.

2.4.8 Total Fatty Acids

It is an indication of the conversion efficiency of the original feedstock. Gas Chromatographic Analysis of Fatty Acids indicates the composition of each of the biodiesels. The largest fraction of fatty acids for each of the biodiesels is a potential indication of the rest of the properties. The methyl esters follow some patterns. The soy, canola, and two yellow grease methyl ester are mostly oleic and linoleic acid (C18, one and two double carbon bonds), while the two largest components of the lard, edible tallow, and inedible tallow methyl ester are oleic and palmitic acid (C18, one C:C bond, and C16, saturated). Free glycerin and total glycerin (by the Christina Planc method) is a good indicator as to the cleanup of the fuel, or of the degree of completion during the reaction. As such, it should remain in the specifications for biodiesel.

2.4.9 Ash content

Ash content measures the amount of ash left after a sample is burned. The presence of ash may indicate undesirable impurities or contaminants. As such, it provides one measure of the suitability of a product for a given application. The maximum acceptable value for diesel meeting D 975 requirements is 0.01%, which should be easily met with most of the biodiesels. Ash content for bio-fuels is typically lower than for most coals, and sulphur content is much lower than for many fossil fuels. Unlike coal ash, which may contain toxic metals and other trace contaminants, biomass ash may be used as a soil amendment to help replenish nutrients removed by harvest.

2.4.10 Water and Sediment

Fuel should be clear in appearance and free of water and sediment. The presence of these materials generally indicates poor fuel handling practices. Water and sediment can shorten filter life or plug fuel filters, which can lead to engine fuel starvation. In addition, water can promote fuel corrosion and microbial growth. The level of water specified is within the solubility level of water in fuel and, as such, does not represent free water. Limits are established to allow measured results to be compared to a maximum level acceptable for proper engine operation.

2.4.11 Copper Strip Corrosion

The copper strip corrosion test indicates potential compatibility problems with fuel system components made of copper alloys such as brass and bronze. The limit specified is the same as that for petroleum diesel fuel.

2.4.12 Carbon Residue

The Carbon residue test is intended to provide some indication of the extent of carbon residue that result from the combustion of a fuel. The limit specified is the same as that for petroleum diesel fuel.

2.4.13 Distillation (boiling point range)

It is the method for determining the full range of volatility characteristics of a hydrocarbon liquid by progressively boiling off a sample under controlled heating. Different methods are available for distillation: atmospheric, vacuum, and simulated. Biodiesel is fundamentally

different than petroleum based diesel, and it is especially evident with distillation. Biodiesel has a fairly homogenous consistency of straight chain hydrocarbons, all with 16 to 18 carbons. Consequently it exhibits a boiling point rather than a distillation curve.

The degree of saturation of the fatty acids attached to the glycerol backbone determines the boiling point of the triglyceride. Generally, the FAMEs, which are mainly comprised of carbon chain lengths from 16 to 18, have boiling points in the range of 330.357 ^{0}C thus the specification value of 360 ^{0}C is easily achieved.

3. MATERIALS AND METHODS

This chapter is about the methodology which was followed to meet the objectives of the study.

- Production of biodiesel which includes extraction and transesterification
- Partial Characterization of the physicochemical properties of the fuel
- Testing the biodiesel and its blend in IC engine for its performance characteristics

Extraction and transesterification of the biodiesel were conducted in wondogenet agricultural research center, chemistry laboratory in Defence Engineering College and chemical engineering department and chemistry laboratory of Adama Science and Technology University while the characterization process of the Biodiesel was done in Ethiopian Petroleum Enterprise (EPE) and chemical engineering department laboratory and materials engineering laboratory of Adama Science and Technology University. Performance analysis of the Biodiesel and the blends were done in Bishoftu Automotive Industry. The chemicals used in the experimentation such as n-hexane for the oil extraction process, methanol and the basic catalyst Potassium Hydroxide (KOH) was in the form of pellet for the trasterification process.

3.1 Production of neem methyl ester

Before the biodiesel is produced, it requires seed collection, neem seed were collected from dredawa and preparation and drying process in order to avoid impurities in the feedstock and avoid the water content of the seed which helps normal tranesterification process to avoid saponification

3.2 Seed Preparation

Oil seeds preparation, which included; samples clearing, drying- to a constant weight in order to reduce its moisture content to reduce the moisture and grinding- in order to weaken or rupture the cell walls to release vegetable fat for extraction of oil.

Figure 3: Neem seed preparation

3.3 Extraction of oil

Extraction of oil was carried out in wondogenet agricultural research center and Adama University chemical engineering department. The extraction process was done by solvent method. In this process, 4.5 kilogram of dried neem seeds was crushed and soaked with hexane. The mixture was stirred repeatedly and settled after 24hrs. The filtered oil solution was fractionally distillated by the apparatus, Rota vapor and the hexane solvent was separated and collected. Finally from 4.5 Kg of neem seeds, 1200 ml of crude oil sample was collected. This crude oil sample was tried for esterification and by taking 100ml of the oil, the exact and appropriate temperature and reaction temperature was reached after three trials of each 100 ml oil sample neem oil was collected.

Extraction procedures performed for the production of oil

1. neem seeds were crushed
2. The crushed powder was soaked with hexane for 24hrs, soaked and stirred, and put in a plastic container**.**

Figure 4 Crushed and soaked neem seeds with hexane

3. The settled oil solution was collected to a glass jar
4. After the solution is settled, it is poured to a flask by filter paper to filter out particles from the solution.

Figure 5: Filtered solution of Crude neem oil and hexane

5. The mixture of oil and hexane solution was separated by Rota vapour until the hexane solution is recovered.

Figure 6: Rota vapour Hexane recovery

6. Finally the crude neem oil was collected in to a separate glass.

Figure 7: Crude neem oil and heating of 100ml oil

3.4 Transesterfication

Neem oil is highly viscous that it cannot be used directly in most existing diesel engines as a straight replacement of petrodiesel. The appropriate method to produce methyl ester for experimental purpose is on batch reaction method. Hence the choice was two stage esterification-transesterification processes. Hence it is important to modify the oil to a lower viscosity so that it is possible to use it directly in the existing diesel engines without any modification.

There are a number of ways to reduce vegetable oil's viscosity. Dilution, micro emulsification, pyrolysis, and transesterification are the four techniques applied to solve the problems encountered with the high fuel viscosity. One of the most common methods used to reduce oil viscosity in the biodiesel industry is called esterification and transesterification, a chemical conversion of the oil to its corresponding fatty ester.

3.4.1 Acid esterification process

1. 200 ml of refined neem oil is poured into the flask and heated up to 60˚C.
2. The 45% v/v methanol is added with the preheated neem oil and stirred for a few minutes. 0.5% of sulphuric acid is added with the mixture.
3. Heating and stirring should continue about 45min at atmospheric pressure.

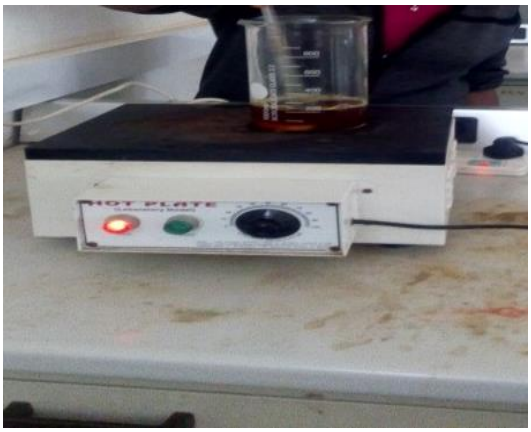


Figure 8: Heating and stirring solution

4. After completion of this reaction, the mixture is poured into a separating funnel for separating the excess alcohol, impurities and sulphuric acid. The excess alcohol, sulphuric acid and impurities move to the top layer and it's discarded. The lower layer is separated for further processing of transesterified into methyl ester. This process reduces the acid value of refined neem oil to less than 1% of FFA.

3.4.2 Alkaline transesterification

1. After acid pretreatment the esterified oil is taken in flask and heated up to 60˚C.
2. 1% of KOH is dissolved in 30% (6:1 M) methanol.

Figure 9: Weighing catalyst

Figure 10: Methaoxilate preparation

3. The dissolved solution is poured into flask.
4. The mixture is heated and stirred for 1hr.
5. On completion of reaction; the mixture is poured into separating funnel left over 24 hr.
6. The glycerol and impurities are settled in lower layer and it's discarded.
7. The impure biodiesel remain in upper layer. It contains some trace of catalyst, glycerol and methanol.
8. The washing process can be done by the 3/4 th of hot distilled water added with methyl ester and gently stirred.
9. The upper layer is pure biodiesel and lower layer is drawn off.

During the traesterification the catalyst is dissolved into the alcohol by vigorous stirring in a small reactor. The oil is transferred into the biodiesel reactor, and then the catalyst/methanol mixture is pumped into the oil and the final mixture stirred vigorously. The reaction produces two liquid phases: ester and crude glycerol. The entire mixture then settles and glycerol is left on the bottom and a methyl ester (biodiesel) is left on top. Washing the methyl ester is a two-step process that is carried out with extreme care. This procedure is continued until the methyl ester layer becomes clear. After settling, the aqueous solution is drained and water alone is added at 28% by volume of oil for the final washing.

Chemically, transesterification means taking a triglyceride molecule or a complex fatty acid, neutralizing the free fatty acids, removing the glycerin, and creating an alcohol ester. This is accomplished by mixing methanol with potassium hydroxide to make potassium methaoxide. This liquid is then mixed into vegetable oil. The entire mixture then settles. Glycerine is left on the bottom and methyl ester, or biodiesel, is left on top.The glycerine can be used to make soap and the methyl ester is washed and filtered.

3.4.3 Methyl Ester Wash

Since both glycerol and alcohol were highly soluble in water, water washing was very effective for removing both contaminants. It also removed any residual sodium salts and soaps.

1. Water was boiled to 50^0C
2. One-third volume of water was taken and filled to a spray gun.
3. Add the water on the bio- diesel

Figure 11: Distilled water

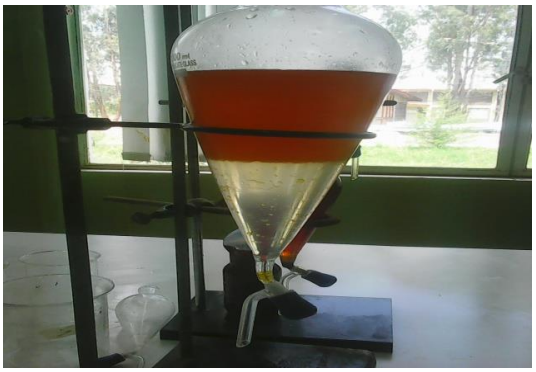


Figure12: Bio- diesel with distill water

4. The Biodiesel was filled in a decanter and hung on a stand.
5. By using the spray gun, the water was sprayed to the oil slowly.
6. The oil was left for 24hrs. hang in a decanter.
7. The water and soap settled at the bottom and was separated by opening the valve of the decanter.
8. The Biodiesel was collected and heated in a furnace for 1hr at a temperature of 100 ^{0}C to evaporate the traces of water left during washing process.

Figure 13 Heating oil 100 ^{0}C

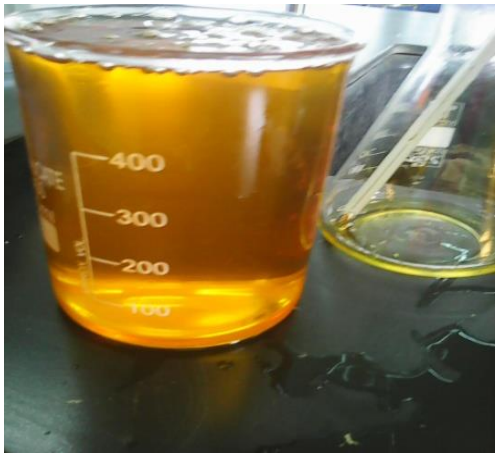


Figure 14: Final collected bio diesel

8. Finally, pure Biodiesel was collected.

3.4.4 Blending of neem biodiesel, with diesel fuel

25ml of neem Biodiesel and 475ml of diesel fuel were measured with a 500ml beaker and stirred thoroughly and to produce B5. The Mixture was allowed to settle for about 4-6 hours for miscibility and consistency. The procedure was repeated for B5, B10 blended fuel respectively.

Table 1: Detail requirement of Biodiesel (B100)

Detail requirement of Biodiesel(B100)				
No.	property	Test method	Limit	Unit
1	Flashpoint	D93	100.0c min	0^{o} c
2	Water and sediment	D2709	0.050max	%volume
3	Kinematicviscosity@40^{o}c	D445	1.6-6centistoke	mm^2/s
4	Sulhated ash	D874	0.020Max	%mass
5	Sulpher	D2622	0.05Max	%mass
6	Copper strip corrosion	D130	No-3 Max	
7	Cetain number	D613(976)	40 Min.	
8	Cloud point	D2500	Report to customer	^{0}C
9	Carbon residue	D4530	0.O50Max	%mass
10	Acide number	D664	O.80Max	mg KOH/g
11	Free glycerine	F	0.020^{G}	%mass
12	Total glycerine	F	0.240^{G}	%mass
13	Calorific value	D2015	report	Calories/gm

3.4.5 Biodiesel Physicochemical Properties Analysis

Determination of Flash point (FP)

Fuels form a flammable mixture with air under controlled laboratory conditions. It is only one of the numbers of properties which must be considered in assessing the overall flammability hazard of a material.

The flash point temperature is a measure of the tendency of the test specimen to flash. Flash point is used in shipping and safety regulation to define flammable and combustible materials. One should consult the particular regulation involved for precise definition of this classification. The U.S Department of Transport (DOT) and U.S Department of Labor (OSHA) have a flash point under 37.8^{0}C or 100^{0} F are flammable, as determined by the test method for those liquids which have a kinematic viscosity of $5.8mm^2/s$ or more at 37.8^{O}c or 9.5mm2/s or more at 25^{O}C or that contain suspended solids or have a tendency to form a surface film while under test.

The flash point as specified not directly related to engine performance. It is however, of importance in connection with legal requirements and safety precautions involved in fuel handling and storage and is normally to meet insurance and fire regulations.

The Pensky Martens Closed Cup Tester was used and the cup was filled 75ml up to mark and heated with an external heater. The agitator ensures that the fuel temperature is uniform. A small open flame was maintained from an external supply of natural gas.

Periodically, the stirrer was stopped and the flame is pivoted down to an opening in the top of the cup to see if the fuel vapor ignites. Just when the flash point has been reached, there was a small flash, and this temperature was recorded as observed temperature and corrected to760 mmHg pressure by applying the correction factor, (ASTM2,2002).

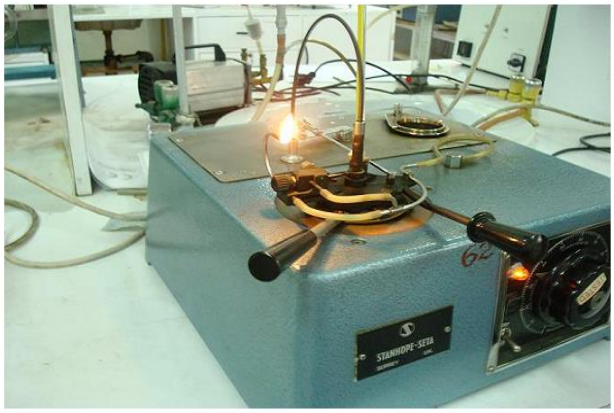


Figure 15: The Pensky-Martens closed cup tester apparatus

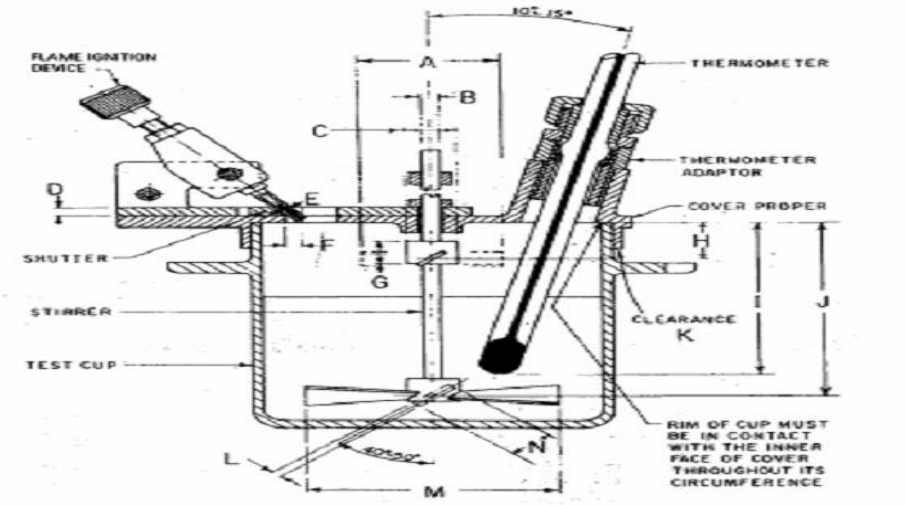


Figure 16: The Pensky-Martens closed cup tester layout.

Calculation of flash point was performed by the following empirical formula.

The observed and recorded ambient barometric pressure at the time of test was different from101.3kPa (760mmHg) and it was corrected for the flash point as follows

Corrected flash point (CFP) = C +0.25 (101.3 -K) Equation 6

Corrected flash point (CFP) = C+ 0.033(760-P)

Corrected flash point (CFP) = F + 0.06 (760 -P)

Where, T = Observed Flash Point Temperature (^{O}C)

P = Ambient pressure (mmHg)

Where C = Observed flash point, ^{O}C

F = observed flash point ^{O}F

K = ambient barometric pressure, Kpa

Determination of Cloud Point (CP)

This test method covers only petroleum products that are transparent and with a cloud point below 40^{0}C. The temperature of the liquid specimen when the smallest observable cluster of wax crystals first appears up on cooling under prescribed conditions. To many observers, the cluster is of wax crystals looks like a patch of whitish or milky cloud, hence the name of the test method. The cloud appears when the temperature of the specimen is low enough to cause wax crystals to form for many specimen, the crystal first form at the lower circumferential wall of the test jar where the temperature is lowest. The size and position of the cloud or cluster at the cloud point varies depending on the nature of the specimen. Some samples will form large, easily observable, clusters while others are barely perceptible. The specimen is cooled at a specified rate and examined periodically. The temperature at which a cloud is first observed at the bottom of the test jar is recorded as the cloud point. The cloud point of petroleum product is an index of the lowest temperature of its utility of certain applications. Mixtures commonly used for temperature reduction are the following:-

1. Ice and water up to 10^{O}C
2. Crushed ice and sodium chloride crystals, up to 12^{O}C.
3. Crushed ice and calcium chloride crystals up to ñ 26^{O}C
4. Acetone, Methyl or Ethyl chloride or petroleum naphtha chilled up to ñ 57^{O}C

The Peltier device was used to measure the CP. As described in ASTM (D 2500), the cloud point was determined by visually inspecting for a haze in the normally clear fuel, while the fuel was cooled under carefully controlled conditions. The sample was continuously monitored and the temperature (^{O}C) that corresponds to the first formation of cloud in the fuel was recorded. And the temperature at which the fuel solidifies is the pourpoint.

Figure 17: The Peltier device apparatus

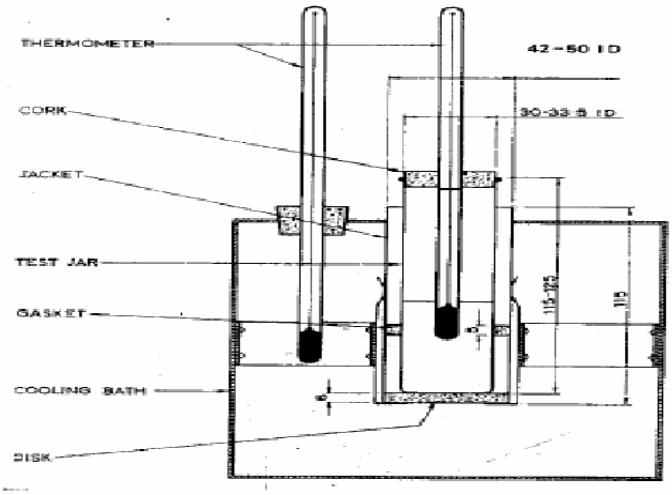


Figure 18: Layout of the Peltieris device apparatus

Determination of Kinematic Viscosity (B5) (ASTM D 445)

This test method specifies the determination of the kinematic viscosity the, of liquid petroleum products both transparent and opaque, by measuring the time for a volume of liquid to flow under gravity through a calibrated viscometer. The dynamic viscosity can be obtained by multiplying the kinematic viscosity by the density, of the liquid. The time is measured for a

fixed volume of liquid to flow under gravity through the capillary of a capillary viscometer under a reproducible driving head and at a closely controlled and known temperature. The kinematic viscosity is the measured flow time calibrated constant of the viscometer. Many petroleum products, and some non petroleum materials are used as lubricants and the correct operation of the equipment depends up on the appropriate viscosity of the liquid being used. In addition the viscosity of many petroleum oil is important for the estimation of optimum storage, handling and operational conditions. Thus, the accurate determination of viscosity is essential to many product specifications.

Cannon-Fenske glass capillary Viscometer Tube was used in a SETA KV-8 viscometer bath and the sample was kept in the bath for 30 minutes to reach the equilibrium temperature of100^{O}C. The time (t) was measured for a fixed volume of liquid to flow under gravity through the capillary of a calibrated viscometer and at a closely controlled and known temperature. The kinematic viscosity is then equal to the product of this time and a calibration constant for the tube.

Viscosity = C x t Equation 7

Where, C = calibration constant

t = time

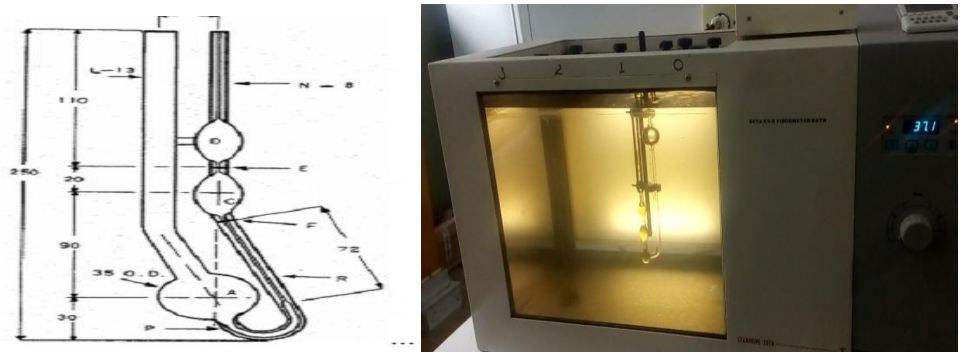


Figure19: Cannon glass Fenske capillary Viscometer Tube in a SETA.KV-8 viscometer bath

The biodiesel fuel characteristics which were measured in Adama University are;-

Determination of Specific Gravity (SG) and Density

This test is done in the university that means by using digital balance

1. W1 = mass of beaker =170.279g
2. W2 =mass of beaker + water =233.35g

3. W3= mass of beaker +bio-diesel =226.96g

So to calculate the s.g

s.g = w3 –w2/w1 which is

= 226.96-170.27/233.35

= 0.899

Figure 20: Measuring beaker +bio-diesel

Determination of Density-To calculate the density first I took empty weight of graduate cylinder (m1) and later took weight of graduate cylinder after filling the water (m2).

M1=49.5 gm

M2=152 gm

By using Verniar caliper measured the dimensions of graduate cylinder and found

Diameter Height=72 mm

Volume=$\pi/4\ D^2h=0.1196\times10^{-3}\ m^3$

Density= Mass/Volume = M2-M1/V= (152-49.5)gm/$0.1196\times10^{-3}\ m^3$

= $860kg/m^3$

Determination of Kinematic Viscosity (pure bio–diesel)

This test method specifies the determination of the kinematic viscosity of liquid fuel on the viscometer that is existed on material engineering department. This viscometer read the amount of viscosity is in CP (centi poise). The amount of bio- diesel viscosity is 76CP

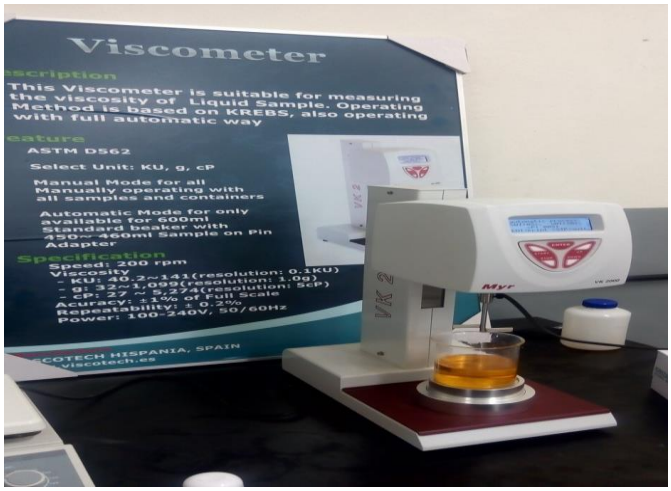


Figure 21: Measuring viscosity of bio-diesel

3.4 Experimental setup for measuring performance Characteristic

Engine test will be carried out for engine performance efficiency. Customers firstly, look for an engine with good output and less fuel consumption. The engine performance characteristics are highly dependent on engine design parameters and operating variables. For a given 12 cylinder T55 tank engine by fixing all operating conditions constant, how two fuels with different chemical structure and from different sources but relatively similar properties will affect engine performance is essential to consider. The heating value of vegetable oil is similar to that of diesel fuel. However, their use in direct injection diesel engines is restricted by some unfavorable physical properties, particularly viscosity, which is usually higher than the diesel fuel. Therefore, use of vegetable oil in direct injection diesel engines creates poor fuel atomization, incomplete combustion, carbon deposition on the injector, and fuel guild up in the lubricant oils resulting in serious engine fouling. Vegetable oil viscosity can be lowered by dilution of oil with a suitable solvent, emulsification, pyrolysis, and transesterification. Biodiesel produced from vegetable oil or animal fats by reacting with alcohol in the presence of catalyst has got similar performance trend when compared with petroleum diesel.

Description of dynamometer

The Dynamometers in Bishoftu Automotive Industry used to measure torque and power over the engine operating ranges of speed and load. They do this by using various methods to absorb the energy output of the engine, all of which eventually ends up as heat. It is Fluid or hydraulic dynamometers absorb engine energy in water pumped through orifices or dissipated with

viscous losses in a rotor-stator combination. Large amounts of energy can be absorbed in this manner, making this an attractive type of dynamometer for the largest of engines.

The experimental setup consist **B2 (two bank)** and T55 tank engine. The engine no of these tested engine is 8AC0327Dl and these engine starts by air. Compression ratio of this engine is 15+ 0.5 and it is naturally aspirated engine it is also will run petro diesel fuel. The engine is directly coupled to a hydraulic dynamometer. Both the engine and dynamometer are mounted on a rigid steel bed plate on the ground, which is free standing on for vibration isolation. The experimental conditions were selected as follows. Eight engine speeds (700, 800, 900, 1100, 1300, 1500, 1700, and 2000 rpm). The fuels were diesel which is a reference fuel and B5

General description of T55 tank engine

Tank T55 is a combat full-truck vehicle having powerful armament, reliable armour protection and high maneuverability. The tank main part are amour hull and turret, armament, power plant, power transmission, running gear, electrical equipment, communication facility, vision devises, anti atomic protection, smoke generating system, and fire fitting equipment. Besides, the tank is provided with under driving equipment. The tank has carried on set of spare parts, tools and accessories.

Figure 22: Tank T72 (general view)

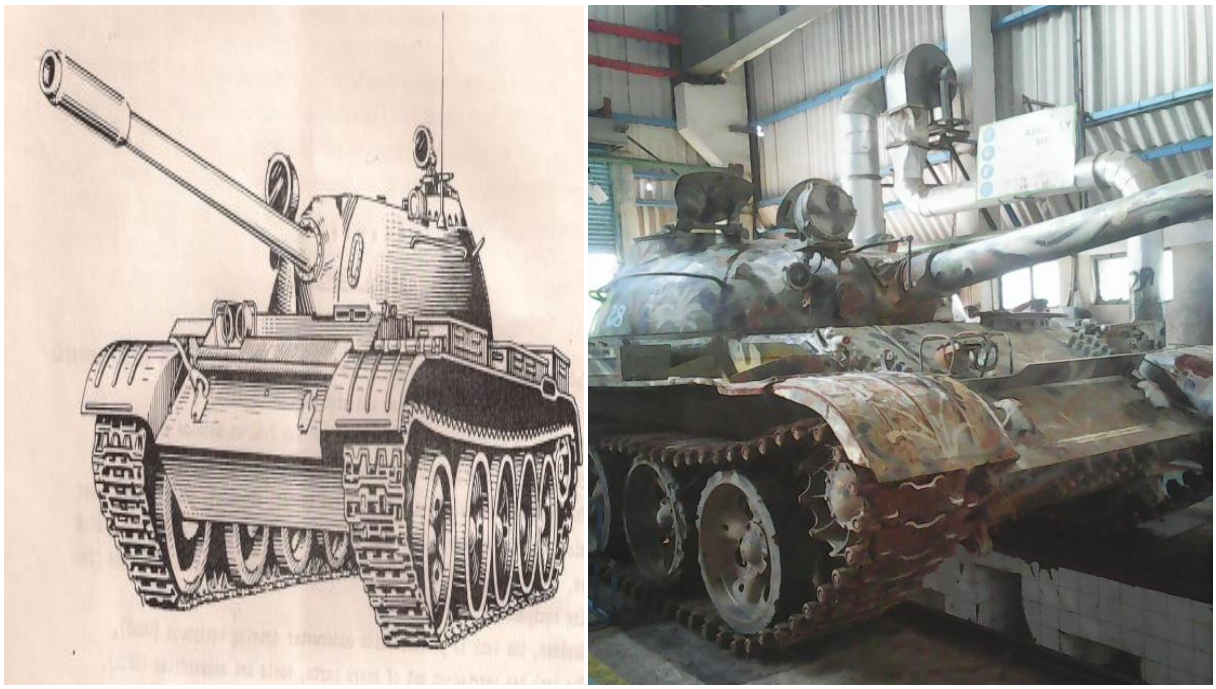


Figure 23: T55 tank (view from the front)

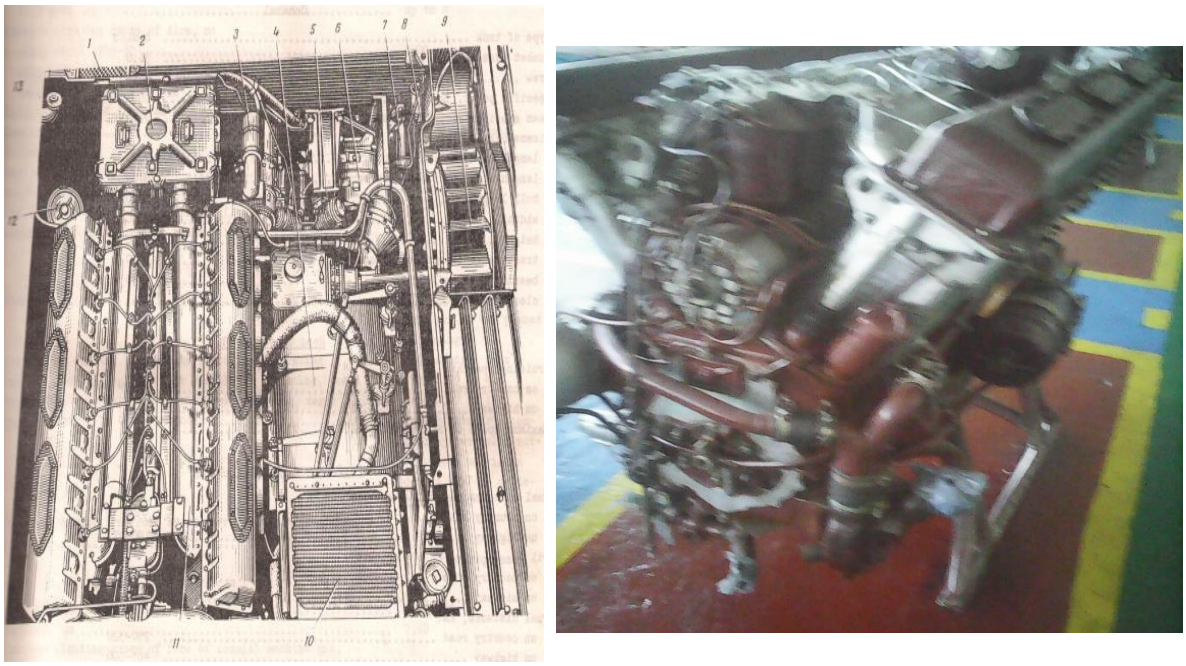


Figure 24: T55 tank engines

Figure 25: Hydraulic dynamometer

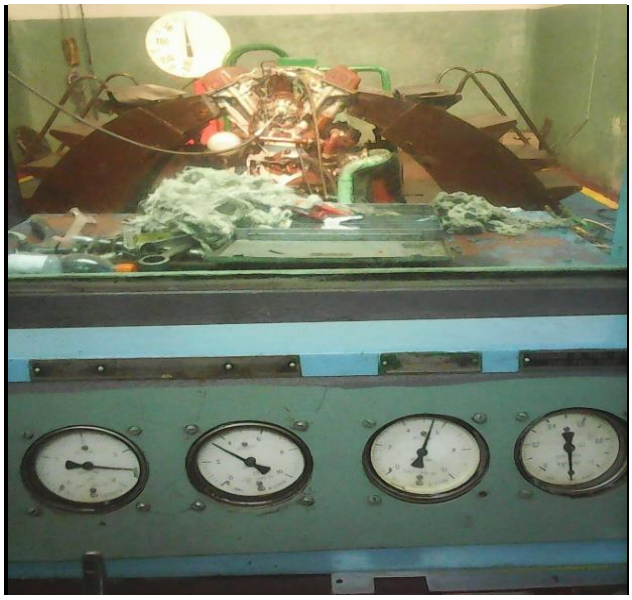


Figure 26: Measuring gauges

Table 2: General Information of the T55 engine

Model and type	B- 55B, and V-type four stroke diesel
Cooling system	Liquid coold
Fuel used	Diesel fuel ДЛ, ДЗ and ДА
Oil used, grade	МТ-16п
Maine starting system	Air starting
Auxiliary starting system	Electric starter
Maximum power at 2000 rpm hp	580
Maximum torque at 1200-1400rpm kgf. M	230±10
Maximum steady idling speed, rpm	500-600
Specific fuel consumption, g/hp/h	190±5
Compression ratio	15± 0.5
Specific fuel consumption , g/hp/h	190±5
Coolant temperature oc	70-90
Oil temperature ^{o}c	70-90
Specific oil consumption , g/hp/h	Not over 12
Cylinder bore	150mm
Stroke	180mm
No of cylinder	12
Method of Loading	Hydraulic Dynamometer
Type of ignition	Compression Ignition
Swept volume	582cm3
Speed range	700 to 2000rpm
Maximum engine speed rpm	2000

3.4 Measured data for performance characteristics

Measured data during the experimentation are shown in the tables below

Table3. Data sheet of neat diesel fuel for T55 tank engine

Time	Rpm	Oil.pre Kgf/cm^2	Left ba.oil Kgf/cm^2	Right ba.oil Kgf/cm^2	Tur.clu Oil pre Kgf/cm^2	Fuel pre Kgf/cm^2	In Wat ^{T0}C	Out wat. Left ^{0}C	Out water. right ^{0}C	Oil in ^{0}C	Oil out ^{0}C	Loa Kgf .m
3:35		8.5	3.5	3.2	5.1	4.4	20	20	20	20	25	-
3:45		9.0	3.5	3.3	4.4	4.4	20	20	20	20	20	-
3:55		8.3	3.2	3.0	5.0	4.8	30	30	25	25	30	-
4:15	900	8.0	3.4	3.4	4.3	4.4	38	42	39	37	42	55
4:25	1150	8.3	3.4	3.0	4.3	4.6	40	48	40	40	45	160
4:35	1300	8.0	3.2	2.8	4.1	4.1	50	60	55	40	50	200
4:45	1400	8.0	3.0	2.8	4.0	4.6	55	65	60	45	60	210
4:55	1500	7.8	3.0	2.9	3.9	5.0	70	80	80	75	75	205
5:5	1750	8.8	3.2	2.9	3.9	5.0	70	80	80	75	75	190
5:15	2000	7.8	3.0	2.9	3.9	5.0	70	80	80	75	75	160
5:25	2100	8.0	3.0	2.9	3.9	5.0	70	80	80	75	75	100

Table 4: Data sheet of oil sample B5 for normal T55 tank engine

Time.	Rpm	Oil.pre Kgf/cm^2	Left ba.oil Kgf/cm^2	Right ba.oil Kgf/cm^2	Tur.clu Oil pre Kgf/cm^2	Fuel pre Kgf/cm^2	In Wat ^{0}C	Out wa. Left ^{0}C	Out wa.. right ^{0}C	Oil in ^{0}C	Oil out ^{0}C	Load Kgf.m
3;35	700	8.3	3.5	3.2	5.1	4.3	20	20	20	20	25	-
3:45	700	9.0	3.5	3.3	4.4	4.4	20	20	20	20	20	-
3:55	800	8.3	3.2	3.0	5.0	4.8	30	30	25	25	30	-
4:15	900	8.0	3.4	3.4	4.3	4.4	38	42	39	37	42	55
4:25	1150	8.3	3.4	3.0	4.3	4.6	40	48	40	40	45	160
4:35	1300	8.0	3.2	2.8	4.1	4.1	50	60	55	40	50	210
4:45	1450	8.0	3.2	2.8	4.1	4.1	50	60	55	40	50	220
4:55	1600	8.0	3.0	2.8	4.0	4.6	55	65	60	45	60	215
5:5	1750	7.7	3.0	2.9	3.9	5.0	70	80	80	75	75	200
5:15	2000	7.7	3.0	2.9	3.9	5.0	70	80	80	75	75	170
5:25	2100	7.7	3.0	2.9	3.9	5.0	70	80	80	75	75	110

From the above experiment we can get the detailed data, there fore

Table5: Data sheet of petro diesel B0

Test number	3	4	5	6	7	8	9	10
Speed(RPM)	900	1100	1300	1400	1500	1750	2000	2100
Brake torque (NM)	55	160	210	220	215	200	170	110
Brake power (KW)	244.2	298.4	347.08	368.4	387.4	416.9	435	373.8

Table6: Data sheet of oil sample B5 for normal T55 tank engine

Test number	1	2	3	4	5	6	7	8
Speed(RPM)	900	1300	1450	1600	1750	1700	2000	2100
Brake torque(Nm)	55	170	210	220	215	200	170	110
Brake power(KW)	244	298	347	368	387	416	440	373

4. RESULTS AND DISCUSSION

The oil extraction process was done by solvent extraction method. In this process, dried neem seeds was crushed and soaked with hexane. The mixture was stirred repeatedly and allowed to settle. The extract was filtered and the solvent was removed under reduced pressure using Rota vapour to get 1.2 liters of crude oil and this oil is ready for esterification. This crude oil sample was tried for transesterification and by taking 100ml of the oil, the exact and appropriate temperature and reaction temperature was reached after four trials of each 100ml oil sample

4.1 Oil Content

30% The yield of oil was found by the solvent method

4.2 Glycerin

The crude oil was converted in to the biodiesel and glycerin. The glycerine and bio-diesel collected in each container

4.3 Important properties of crude neem biodiesel and tested diesel fuel

The result of the experimentation was as shown on the table below and all the selected parameters are tested as to the test method indicated and all have satisfied the requirement and all the parameters are obtained in the accepted range as shown below when compared to the values of ASTM standard test method.

Table7: Important properties of tested neat diesel fuel and CNOME

Properties	Diesel	Limit	CNOME	B5	B10	ASTM code
Specific gravity by using calculation	0.836		0.899			
Density in Kg/M^3			860			
Kinematic Viscosity @ 40 ^0C mm^2/sec	3.7	1.9-6.0		4.0		D445
Flashpoint(PMCC)^oC min	90	93	109	90	90	D93
Cloud point ^0C max	2.5	+5	+4	+3	+3	D2500

4.4 Performance characteristics

The research was mainly concentrated on investigating and comparing the engine performance tidy diesel with B5 blend ratio for eight engine speeds. The dynamometer in Bishoftu Automtotive Industry is only measures the engine torque with relation to engine rpm. The experiment was starts to conduct when the engine rpm is 900 and the engine temperature is 50^0c. So by supplying varying loads the performance of the engine was measured.

Table below illustrates the engine outputs at low to full load. A close resemblance occurred at low speed indicating little difference in output between the fuels that means at low speed simple torque variation. However, at higher speed, a clear gap appeared between the alternatives and reference fuel was view. With the experiment it is observed that the torque of the test engine is increasing with increase in engine speed

Torque characteristic As the engine speed increase the torque also increase, maximum torque for both type fuels were obtained rpm around 1500rpm and maximum power was at 2000rpm. However, the torque variation among diesel fuel and the blends was slightly higher at medium to higher speed and closer pattern was observed at minimum rpm operations.

Table 8: Torque with various engine speed

Engine Speed (RPM)	B0 torque (Diesel) (Nm)	B5 torque (5% biodiesel & 95% diesel) (Nm)
900	55	55
1150	160	130
1300	200	170
1400	210	200
1500	205	230
1750	190	200
2000	160	170
2100	100	110

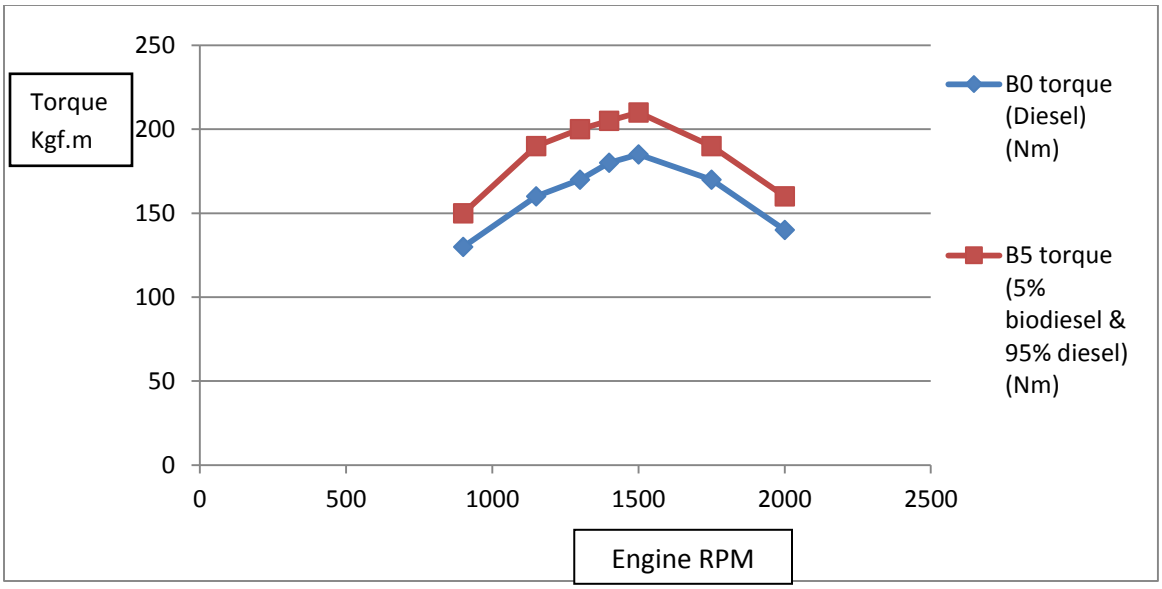


Figure 27: Torque Vs Speed Curve for B0 and B5

Power characteristic**:** The dynamometer is usually measures the engine torque from this torque we can get the brake power by using the formula.

$$Pb = \omega T$$

Where ω = angular velocity of crankshaft = $\frac{2\pi N}{60,0000}$ rad/sec

Where N = rpm of Engine

T = Torque of the engine in N-m

Where Tb, Brake torque in N-m

Therefore, $Pb = \frac{2\pi N T}{60,000}$

The engine outputs at low to full load close resemblance occurred at low speed indicating little difference in output between the fuels. However, at higher speed, a clear gap appeared between the alternatives and reference fuel. The overall brake power increase for blend was expected because neat CNOME has got higher viscosity. That is why it is good for high compression ratio engine.

Table 9: Power and engine speed

Engine Speed (RPM)	Brake power for B0 (Diesel) (KW)
900	125.5
1150	298.4
1300	347.07
1400	387.42
1500	416.89
1750	422.56
2000	430
2100	400

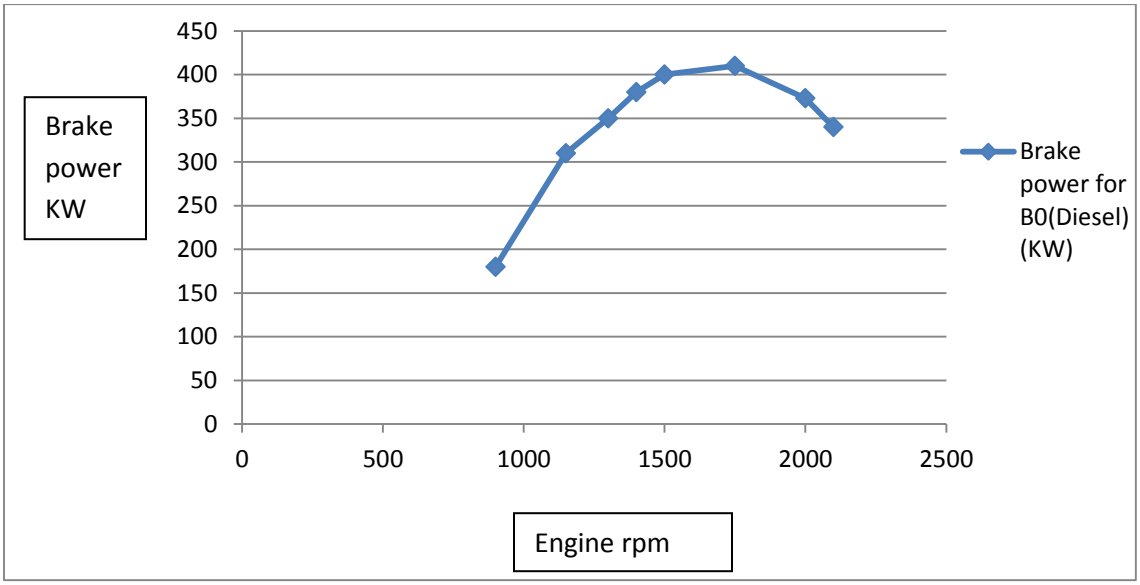


Figure 28 power Vs Speed Curve for B0

Table 10: Power and engine speed B5

Engine Speed (RPM)	Brake power for B5 (Diesel) (Kw)
900	226
1150	310
1300	350
1400	390
1500	400
1750	440
2000	373
2100	340

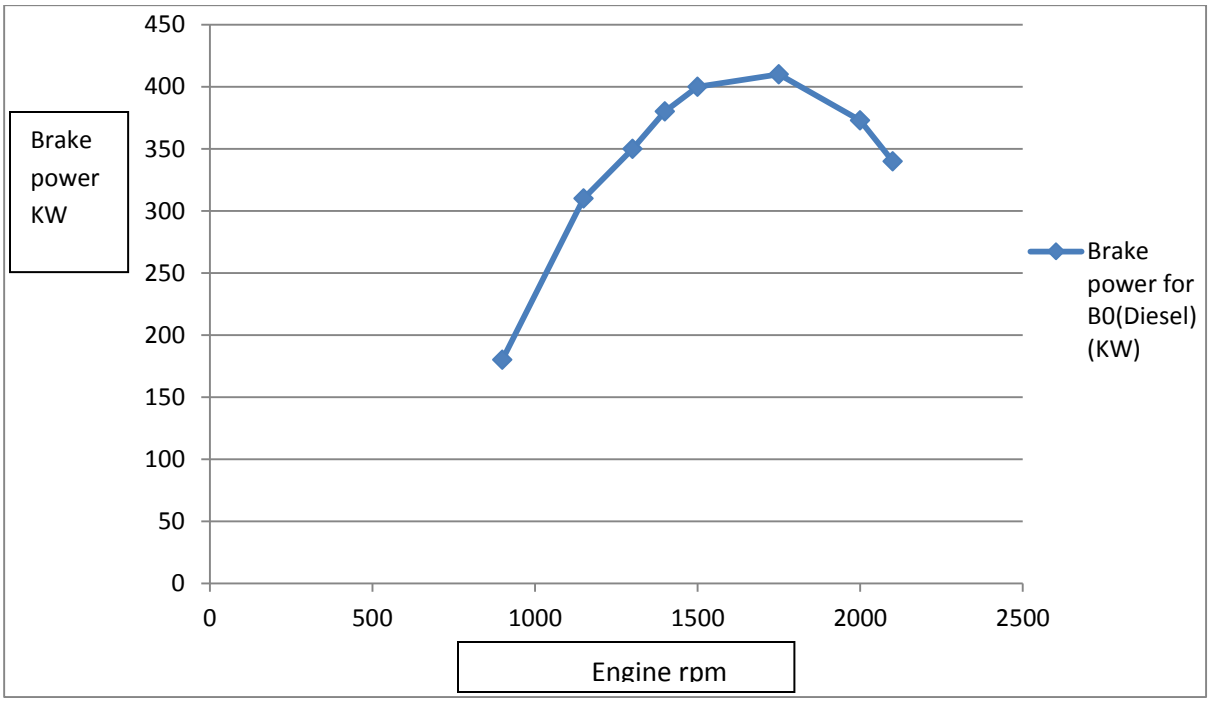


Figure 29: Power Vs Speed Curve for B5

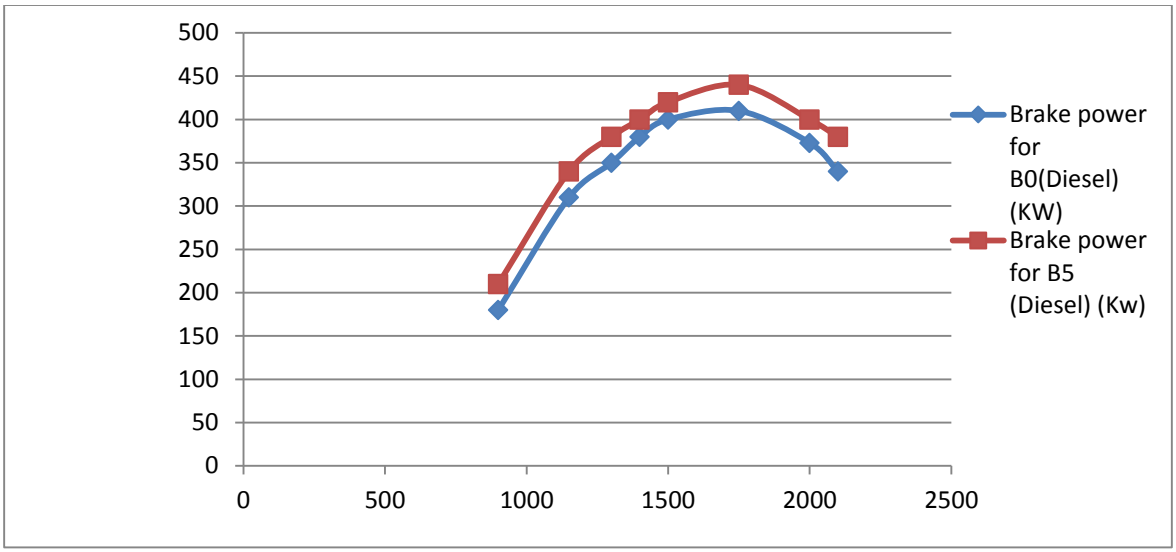


Figure 30: Power Vs Speed Curve for B0 and B5

4.4.1 Exhaust emission characteristics

Diesel engines usually exhaust higher amounts of particulate matter (PM) than spark ignition engines. Many alternative diesel fuels have been shown to have better exhaust emissions than traditional diesel fuel. Alkyl esters of vegetable oils and animal fats, called bio diesel, hold promise as fuel alternatives for diesel engines. Ramadhas atal. (2004) suggested that biodiesel has fuel properties and provides engine performance that is very similar to diesel fuel.

The primary incentive for using biodiesel is that it is a nontoxic, biodegradable, and renewable fuel. Further advantages over petroleum based diesel fuel include a high cetane number, low sulfur, low aromatics, low volatility and the presence of oxygen atoms in the fuel molecule. These features of biodiesel lead to its greatest advantage, which is its potential for emission reduction including CO, HC, solid carbon particles (SOP) and PM. But making petro diesel standard biodiesel is not simple.

Hence making your own fuel (biodiesel) should start with experiment to find suitable fuel, because the fuel quality depends on the fatty acid composition of oil, method of oil extraction, careful transesterification, safety handling and storage.

Exhaust gas analysis was not done due to non availability of analyzer In Bishoftu Automotive Industry. The people in Bishoftu Automotive Industry checking the exhausts gas by simply visual inspection.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this work crude Neem oil extracted on small scale was selected for biodiesel production. Neem methyl ester was produced by means of esterification- transesterification process using crude Neem oil, which can be described as a renewable energy sources. A maximum of 75% biodiesel was produced with around 30% methanol in presence of 3% sulfuric acid and 1% potassium hydroxide by acid treatment followed by alkali transesterification at reaction temperature 60^0C.

Biodiesel characterization was done in national petroleum fuels organization, and Adama University the result of selected important properties in the range of ASTM D6751 and EN14214 biodiesel specifications. Neat Neem methyl ester has got slightly higher kinematic viscosity, flash point and density, but it may have lower heating value and cold flow properties as a bio-diesel.

The engine test was carried out in a twelve cylinder T55 tank diesel engine with neat diesel to take base line, and with B_5, to evaluate the performance characteristics of bio-diesel blend. Performance parameters of the engine with B_5 bio-diesel blends were investigated and compared with that of diesel fuel. The brake power and brake torque was generally higher than throughout the engine speed range. The increment in brake power is more at higher engine speeds.

As we know from many research experiment, biodiesel fuel has considerable improvement in emission can be obtained under part and full load operation of the engine. The biodiesel fuels produce less CO, HC and CO_2 emissions than diesel it has higher under similar engine operating conditions, probably because bio-diesel contains oxygen and other fuel related properties which helps the combustion in the cylinder and it will increase the concentration of NOX.

T55 12 cylinder tank engine generally B_5 had shown better performance characteristics as compared to conventional diesel fuel. Hence B_5 blend of Neem bio-diesel can be considered as a better replacement fuel for diesel in conventional tank diesel fuel system for moderate temperate climatic zones. As my opinion by increasing the blend percentage, can increase

farther the performance of T55 engine, but to increase blend percentage comprehensive research should be done to evaluate performance and emission parameters by considering large number of parameters.

A general conclusion regarding the biofuels can be made comparing the lighter and heavy diesel engines. For the compression ignition engine with high compression ratio the blended fuel gives a higher torque and brake power. However, for lighter diesel engines the blended biofuel shows a lower torque and brake power.

5.2 Recommendations

In my work lab scale batch process was used for ester production. The process was not monitored electronically and reactant mixing was manual, which is not more precise and also time consuming. Here no attempt is done to recover alcohol and glycerol. Hence for mass production continuous process rather than batch process is more practical.

The overall system should compromise basic functional groups for pretreatment of FFA by acid catalyst (H_2SO_4), because crude neem oil contains as high as FFA and minor impurities, transesterification on basic media, methanol recovery, and glycerol recovery, water washing and drying. Adequate recovery of alcoholisms reaction by products and efficient post treatment of recovery products will add more value. Additionally oil extraction by product adds more value if they are conveyed for further processing.

Important properties of biodiesel are dependent not only on the type of feed stock also on accuracy and control of production process. Before starting the ester production process the crude oil must be free from water and impurities, so that adequate purification and water evaporation is needed. During reaction controlling molar ratio of reactants reaction time, temperature, catalysts are very essential. There for computer monitored control of overall production process and sample characterization is recommendable before usage and Water and impurity free storage and safety handling system is essential.

Bio-diesel engine test

Although the amount of testing desired at the beginning of the study was not obtainable, the testing that was done provides a good baseline for future work. This section presents a variety of recommendations for future work in this ongoing energy solutions project. Especially for

Bishoftu Automotive Industry I want to recommend facilitating all the engine testing equipment including dynamometer which has all the testing parameter and exhaust gas analyzer in order to test the amount of pollutants in the exhaust gas.

Data Acquisition and analysis

The performance characteristics of tank engine were read manually from dynamometer in separating room and this dynamometer measure only the engine torque installed on its board, which proved time consuming. Automatic data acquisition would greatly improve the speed and accuracy of tests. It is important to determine how these values change with fuel properties and exhaust emissions. A shaft position encoder will also be required for this measurement.

Final Notes

Since compression ignition engines are designed and tuned for use with diesel fuel, it seems logical that fuels with different properties, such as biodiesel, may require some engine adjustment in order to combust optimally. The most likely manifestation of non optimal burning is increased NOx emissions. Mitigation of this may be as simple as retarding the fuel injection timing slightly. It should be noted that these effects are engine dependent, and some engines may require no adjustment at all. Another option is to use fuel additives that bring the relevant properties of biodiesel closer to those of diesel. This is speculation only and requires further testing to be verified.

Finally, doing further research is required to get a clear data with various amount of blending ratio. The above experiment is restricted to do the test with B5 only because tank engine is high compression ratio and 12cylinder with a large cylinder diameter that is why restriction is existed. Defense must focus on the production of bio-diseal to use as an alternative fuel for the tank engine.

APPENDEX

Appendix: A

Table A1: Cost Analysis

S.No	Material	Unit	Quantity	Unit price	Total price (ETB)
1	Neem seed	Kg	60	60	3600
2	Methanol	Liter	1	300. 87	300. 87
3	KOH	Kg	0.5	660.87	660.87
4	NaOH	Kg	0.5	600	600
5	Distilled water	Liter	8	10	80
6	Diesel fuel	Liter	22	15	330
7	Plastic reservoir	psc	3	15	45
8t	Transport cost	-	-	-	1500
9	Labour cost	-	-	-	1000
10	Other	-	-	-	500
11	soap	-	-	-	200
12	Rag	Kg	-	-	200
12				**Total**	9216.74

Appendix: B

Engine test experimental procedures

Start-up Procedure

1. Turn laboratory ventilation fans on high.

2. Check engine oil

3. Check water level on the tanker

3. Visually inspect test stand and engine (oil/fuel leaks, disconnected wires, etc)

Figure A1: Inspection of dynamometer

4. Check fuel level

5. Close laboratory doors

6. Wear noise damper

Figure A2: Gauges and lever of Dynamometer

7. Push throttle fully

8. Start the engine by compressed air hydraulic dynamometer also starts

10. Idle engine up oil temperature is $20^{o}c$

Figure A3: Temperature and pressure gauge

11 checking engine oil pressure

12. Increase RPM to 1100 by slowly pushing throttle forwards and adjusting the load control

16. Once engine temperature reaches 50 ^{0}c and above, testing can be started.

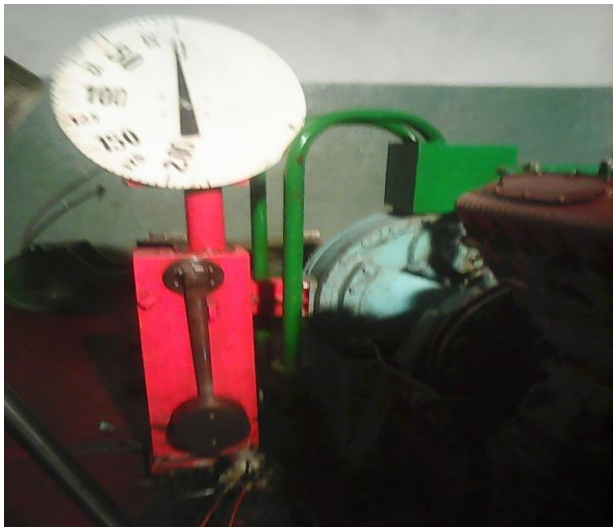


Figure A4: Dynamometer reading

Shutdown Procedure

1. Reduce speed and Idle engine for at least 3 minutes after any testing.

2. CAUTION: Exercise extreme care when entering laboratory. The engine will be very hot.

3. Check engine for any leaks or obvious problems.

4. Turn off laboratory ventilation fans

REFERENCES

[1] Anatolian, J. Wiley, M.L. Allen, 2002, the effect of the amount of catalyst, alcohol, and tanktemperature on the purity of ester obtained from the transesterification of sunflower oil in a batch stirred reactor, Germany.

[2] **A.** Azhar Abdul, S. Mohd Farid, A. Mohamad Afiq, S. Mazlan, 2007,The Effects Neutralized Palm Oil Methyl Esters (NPOME) on Performance and Emission of a Direct Injection Diesel Engine, Automotive Development Centre, Faculty of Mechanical Engineering, Malaysia,

[3] Barnwal.B.K and M.P. Sharma, 2005, Prospects of bio diesel production from vegetable oils in India, Renewable and Sustainable Energy Reviews, 9, 363-378.

[4] Biodiesel and Renewable Diesel Advisory Group, 2009, Biodiesel and Renewable Diesel Emissions Study and Biodiesel Multimedia Evaluation, March 12, 2008

[5] Canakci, M and Van Gerpen, J., 2001. Biodiesel production from oils and fats with high free fatty acids, Transactions of the ASAE, 44(6): 1429-1436.

[6] Crabbe, S. Jayraj,C.Muralidhan, 2001, Transesterifiction process of crude palmoil by acid catalyst, International Journal of Life Cycle Assessment

[7] Darren S., Leif N., Mathew Ch.,Sean H. ,2005, Biodiesel Engine Testing

[8] D. Darnoko1 and Munir Cheryan, 2000, Kinetics of Palm Oil Transesterification in a Batch Reactor,University of Illinois,Department of Food Science and Human Nutrition, Agricultural Bioprocess Laboratory, Urbdna, Illinois 61801

[9] Dr. J.G. Suryawanshi 2009 , Palm Oil Methyl Ester: A New Fuel for CI Engines

[10]Dr.R. Marappan T.Balusamy, 2007, Comprehensive analysis on performance, combustion and emission characteristics fueled by various blends of corn oil, palm oil bio diesel.

[11] Heywood, John. B, 1988, Internal combustion engine fundamentals, Singapore

[12] Knothe, 2009, the Biodiesel Handbook, Chaper 2 - The History of Vegatable Oil Based Diese Fuels

[13] Kemp, William.2006, Bio diesel: Basics and Beyond. Canada: Aztext Press, 2006.

[14] Knothe, G., 2001, Historical Perspectives on Vegetable Oil-Based Diesel Fuels, INFORM, Vol. 12(11), p. 1103-1107 (2001), Retrieved, 2007-07-11.

[15] Kumar.R, M.Sharma, S.S.Ray, A.S.Sarpal and A.A.Gupta, 2004, Biodiesel from jatropha curcas and pongamia pinnata, SAE 2004-28-0087

[16] Leenus Jesu Martin.M, D.Prithiviraj and K.C.Veleppan, 2005, Performance and emission characteristics of a CIengine fueled with esterified cotton seed oil, SAE 2005-26-355.

[17] Maycock, J.H.,2006, Extraction of Crude Palm Oil, in Palm. Oil, edited by F.D. Gunstone, Cri l. Rep. Appi. Chem., John Wiley & Sons, New York, Vol. 15, 1987, pp. 29-38,

[18] Milwaukee, Wisconsin, USA, 1983, SAE Technical Paper series no. 831356. SAE International off Highway Meeting,

[19] M. Nagarajan, 2008, Bio fuel development in Malaysia, Thailand

[2) National Bio diesel Board, 2007, Chrysler Supports Bio diesel Industry; Encourages Farmers, Refiners, Retailers and Customers to Drive New Diesels Running on Renewable Fuel.

[21] National Bio diesel Board (2005-10),Energy Content,. Jefferson City, USA, 2007-11-20

[22] Naveen Kumar2004,Fuelling an agriculture engine with derivative of palm oil, SAE2004-

[23] New Bio diesel Blend Specifications, Published by ASTM International, Retrieved, 2009-

[24] Noureddini, H and Zhu, D. 1997. Kinetics of transesterification of soybean oil, JAOCS, 74(11): 1457-1463.

[25] Oguntola J Alamu, Nurudeen O. ADEKUNLE and Salam O. ISMAILA,2009 , Power and Torque Characteristics of Diesel Engine Fuelled by Palm-Kernel Oil Bio diesel.

[26] Prateepchaikul, G., Allen, M.L., Leevijit, T. and Thaveesinsopha, K., 2007 Methyl ester production from high free fatty acid mixed crude palm oil Songklanakarin J. Sci. Technology.

[27 Ramadhas, A.S., Jayaraj, S. and Muraleedharan, C. 2005. Biodiesel Production from High FFA Rubber Seed Oil. Fuel, 84(4): 335-340. Elsevier Science Ltd.

[28] Ramadhas.A.S., S.Jayaraj, and C.Muralidharan, 2004, Use of vegetable oils as IC engine fuels- A review, Renewable Energy, 29, 727-742.

[29] Ramesh.A and J.Narayana Reddy, 2006, Parametric studies for improving the performance of jatropha oilfuelled compression ignition engine, Renewable Energy – 31, 1994-2016.

[30] Saifuddin, N. and bK.H. Chua 2004, Malaysian Journal of Chemistry, 2004, Vol. 6, No. 1, 077 – 082, Production of Ethyl Ester (Biodiesel) from used Frying Oil:

[31] Shay, 1993, Transesterification processes to produce methyl ester.

[32] Suryawanshi.J.G and N.V.Deshpande, 2004, Experimental investigation on pongamia oil methyl ester fuelled diesel engine, SAE 2004-28-0018

[33] S. Kumar, D. Maheswar, K. Vijaya Kumar Reddy, 2009, Comparision of Diesel Engine Performance and Emissions from Neat and Transesterified Cotton Seed Oil, Jordan Journal of Mechanical engineering.