ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Mechanical Chemical and Materials Engineering

AN EXPERIMENTAL STUDY FOR THE PERFORMANCE OF THE REPRESENTATIVE BIODIESEL FUELS COMPARING TO THE CONVENTIONAL DIESEL FUEL

A project submitted in partial fulfillment of the requirements for the Award of the Degree of Master of Science in Automotive Technology

by

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CANDIDATE'S DECLARATION

We hereby declare the work which is presented in the project entitle TESTING THE PERFORMANCEOF LINSEED OIL BIODIESEL-ETHANOL AND DIESEL IN DIESEL ENGINE A Project submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive Technology of is an authentic record of our own work carried out from February 2016 to june2016 under the supervision of Chul-Ho Kim (Prof), Department of Mechanical and Vehicle Engineering, Adama Science and Technology University.

The matter embodied in this project has not been submitted by us for the award of any other degree or diploma. All relevant resources of information used in this thesis have been duly acknowledged.

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DEPARTMENT OF MECHANICAL SYSTEM AND VEHICLE ENGINEERING

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ABBREVATION AND ACRONYM

ASTM	American society of Testing and Material
BMEP	Brake mean effective pressure
BSEC	Brake specific energy consumption
BSFC	Brake specific fuel consumption
CN	Cetane No
CP	Cloud Point
CFPP	Cold filter Plugging Point
CPO	Crude Palm Oil
CSTRS	Continuous Stirred Tank Reactors
CVS	Constant Volume Sampling
CEN	European committee for standardization
HCL	Hydrochloric acid
CDRI	Compression Ratio of Direct Injection
CRGE	Green Economy
DME	Di methyl ether
ETB	Ethiopia birr
FFA	Free Fatty Acid
FAME	Fatty Acid Methyl Ester
FIE	Fuel Injection Equipment
FP	Flash Point
GHG	Green house gases
GTP	Growth and Transformation Plan
H_2SO_4	Sulphuric Acid
HHV	Higher Heating Value
HC	Hydrocarbon

IV	Iodine value
KOH	Potassium Hydroxide
MT	Million Tones
Mg	Milligram
MDGS	Millennium Development Goals
MOE	Ministry of Education
MSDS	Material safety data sheet
NO, NOx	Nitrogen Oxides
NAOH	Sodium hydroxide
NCO	Net coconut oil
NHP	Non – hydro table phospholipids
OEM	Original equipment Manufacturer
PP	Pour Point
PM	Particulate Matter
PPM	Parts per Million
PFRS	Plug flow reactors
SOF	Soluble Organic Fraction
SV	Saponification Value
SME	Soybean Methyl Ester
SO_2	Sulfur Oxides
SCR	Selective Catalytic Reduction
TVET	Technical & Vocational Educational training
THC	Total hydrocarbon
EN	European committee for standardization

ABSTRACT

The depleting reserves of petroleum and environmental issues have led to the search for more environmental-friendly and renewable fuels. Biodiesel obtained from various bio sources is one of the better alternative fuels due to its biodegradability, high cetane number, no sulphur emissions and low volatility. Biodiesel derived from non-edible feed stocks such as linseed oil and others are reported to be feasible choices for developing countries including Ethiopia, where consumption and cost of edible oil is very high.

The aim of this project is to produce biodiesel from linseed oil and test its performance in diesel vehicle by blending with diesel and ethanol. Biodiesel was produced from linseed oil by using transesterification process. Biodiesel was characterized. The blend of B0,B10 and B10E5 were prepared.

A performance test was conducted on diesel vehicle equipped with four cylinder four stroke diesel engine with diesel and blends as fuels. The performance parameters like wheel power, wheel torque were measured in full throttle position at in different gears at different vehicle speeds. Brake torque, brake power and brake specific fuel consumption of the engine was calculated at different engine speeds. brake power of B10 and B10E5 was observed to be lower by 3.3kW and 6.25kW receptively when compared to conventional diesel fuel, the brake torque of B10 and B10E5 was observed to be lower by 5.97Nm and 11.63 Nm when compared with conventional diesel fuel and specific fuel consumption observed to be higher by 15.97gm/kW hr and 35.27gm/kW hr when compared with conventional diesel fuel. Maximum brake torque decreases by 3.19% for B10 and 6.01% for B10E5 and brake power decreases by 4.85% for B10 and 9.19% B10E5 were compared to conventional diesel fuel and brake specific fuel consumption is increases with the increase in engine speed. Depending on the experimental observation B10 and B10E5 were better at low and medium vehicle speed.

Keywords: *Biodiesel, Transesterification, Ethanol, Diesel, Brake power, Brake torque.*

1. INTRODUCTION

1.1 Background of the study

Due to scarcity and increasing costs of conventional fossil fuels, biodiesel fuel has become more attractive. Experts suggested that current oil and gas reserves would tend to last only for few decades. To fulfill the rising energy demand and replace reducing oil reserves renewable fuel like biodiesel and ethanol additives are within the forefront of other technologies. Biodiesel and ethanol have proved to be a possible alternative for diesel in compression ignition engine. Biodiesel burns like petroleum diesel as it involves regulated pollutants. Diesel fuel can be replaced by biodiesel made from vegetable oils and ethanol as an additive. Biodiesel is now mainly being produced from soybean, rapeseed, palm oils and Linseed. In developed countries, there is a growing trend toward using modern technologies and efficient bio energy conversion using a range of bio fuels, which are becoming cost wise competitive with fossil fuels [1]. In Ethiopia some special advantages in taking up plantation of tree-borne oil seeds for production of bio diesel due to vast unutilized land. The use of biodiesel results in substantial reduction of un-burnt carbon monoxide and particulate matters. It has almost no sulphur, no aromatics and more oxygen content, which helps it to burn fully. Its higher cetane number improves the combustion. Sunflower and rapeseed are the raw materials used in Europe whereas soyabean is used in USA. Thailand uses palm oil, Ireland uses frying oil and animal fats. In India vast research has been done on biodiesel from jatropha oil. It is proposed to use vegetable oil for making biodiesel, in Ethiopia. Our project aim is to use linseed oil as a replacement along with conventional diesel to minimize the problems associated with petroleum fuel.

1.2. Statement of the problem

When we study a problem, the major problem which concerned the world is a greenhouse effect, fluctuation of oil price depleting reserves of petroleum and high demand of energy over the world. Due to using pure Diesel fuel as engine fuel it increases the amount of emission which are CO_2, CO, HC and NOx in the atmosphere. Therefore to overcome the emission and other problem biodiesel and ethanol had been tested for its suitability for using as a fuel in diesel engine. So finding renewable, nonpolluting, home grown, cost wise alternating fuel is necessity.

1.3. Objectives

1.3.1. General Objective

The general objective of this project is to test the performance of biodiesel produced from linseed oil and its blend with diesel and ethanol in diesel vehicle.

1.3.2. Specific objective

The specific objectives for this project are as follows:

- To Extract oil from linseed
- To produce biodiesel of linseed oil, blend with ethanol and diesel.
- To characterise linseed biodiesel.
- To compare the performance of biodiesel and its blends with diesel and ethanol in diesel vehicles.

1.4. Significance of the study

The project will indicate how and why the alternative fuel is used instead of using pure Diesel fuel and may increase the interest of the owners of the car to use alternative fuel. After the accomplishment and implementation of the modification of fuel is expected to have the following basic significance:-

- Reduce the net emissions of greenhouse gases.
- Minimise the need for foreign-produced oil.
- Limit amount of high cetane additives.
- Farmers see an increased demand for grain which helps to stabilize prices.
- The quality of the environment improves. Carbon monoxide emissions reduce.

1.5. Delimitation of the study

It is delimited to conduct performance test with the blend of linseed oil 10%, Ethanol 5% and diesel 85% proportions of mixture due to time constraint in a four cylinder four stroke self-ignition engine

1.6. Limitation of the study

Chassis dynamometer was used for testing performance because engine dynamometer not functioning. Due to malfunctioning of the available exhaust gas analyzer, the exhaust gas analysis was not done. The experimentation was done only for certain blends due to time constraint.

2. LITERATURE REVIEW

2.1 Introduction

The energy demand, environmental concern of the global warming and climate change and increasing petroleum price in the worldwide has greatly increased the interests of the application study of alternative fuels to internal combustion engine. Among these alternative fuels, biodiesel and diesohol (diesel – ethanol blends) have received much attention in recent years for (CI) engines. Ethanol is regards as a renewable fuel because it can be made from many types of raw materials such as corn, sugar cane, sugar beets, molasses, cassava, waste biomass materials, sorghum, barley, maize, etc. [2, 3].

The literatures reported the study of kinetics and simulation of alkali-catalyzed transesterification of linseed oil in a batch reactor. They investigated the effects of temperature, catalyst concentration, and molar ratio on the conversion rate from triglyceride to methyl ester. The equilibrium conversions of approximately 88–96% in 40 minutes were found. They stated that with increase in temperature by 10°C an increase of 2–3% in equilibrium conversion was achieved. They observed that catalyst concentration of 0.5–1.0% had no significant effect on equilibrium conversion. An increase of 1–3% in equilibrium conversions were observed with an increase in molar ratio from 6:1 to 9:1. They estimated the overall activation energies of 6.50 kcal/mol and 6.37kcal/mol with 0.5% and 1.0% NaOH catalyst respectively .They observed that there was not any significant increase in the equilibrium conversion for molar ratio greater than 12:1.They compared the properties of non-edible oils and biodiesel produced with that of mineral diesel. They observed that due to transesterification process there was a significant decrease in kinematic viscosity of vegetable oils, Due to the improvement in the other properties of biodiesel with the transesterification process they stated that the biodiesel derived from non-edible.[51].

Other literatures observed the effect of varying the injection pressure on performance, emission and combustion characteristics of high linolenic linseed oil methyl ester in a DI diesel engine. They noticed that at 240 bar injection pressure, the efficiency of engine was nearly same as that of engine operated on diesel. They noticed that at 200 bar injection pressure the carbon monoxide; hydrocarbon and smoke emissions were lower than with diesel. They also noticed the nitrogen oxide emissions were slightly increased with linseed methyl ester. They analyzed that

ignition delay was lower at higher injection pressure compared to diesel and also peak pressure was higher. They also founded that although thermal efficiency was higher at 240 bar injection pressure but emissions were increased. According to them this may be due to the change in fuel spray structure at higher injection pressure. They observed that thermal efficiency was decreased in compare to diesel at 200 bars. At last they concluded that the performance and emission characteristics were improved at 240 bar injection pressure with linseed methyl ester in DI diesel engine.[52].

HiregoudarYerrennagoudaru, et al. (2014) they analyze the fuel consumption and emission characteristics of a twin cylinder diesel engine using bio-fuels and compared with ordinary diesel. They study the brake thermal efficiency, BSFC, and emission at zero load and full load with bio-fuels. The fuel proportion is 30% ethanol + 70% linseed oil. Engine setup consists of twin cylinder diesel engine, 4 stroke, and forced cooling system. Also multi gas analyzer, monitoring kit for PM for performance and emission analysis. Injection timing is 27 BTDC (static), the opening pressure of nozzle set at 170 bars and speed at 1500 rpm. The observations are, at different loads the BSFC of bio-fuel is more than diesel. Because results lower energy substitute bio-fuel thus engine respond to load. From the analysis the bio-fuel shows better performance than diesel. Decrease in emission parameter and increase in performance characteristic. Hence, it is conclude that bio-fuel can be used as substitute for diesel [48].

H. B. Parikh, et al. (2013) they described the use of ethanol/diesel mixtures increases the ignition lag time due to low cetane number of ethanol. A single cylinder, 4 stroke, water cooled CI engine manufactured by Rocket Engg. Corporation Ltd. was used in the investigation. The engine was run about 30 min. till to reach steady state. The fuel proportions are 80% diesel+15% biodiesel+5% ethanol D80B15E5, 70% diesel+20% biodiesel+10% ethanol D70B20E10, 70% diesel+25% biodiesel+5% ethanol D70B25E5. The observations recorded were brake load reading, engine speed, exhaust gas temperature, cooling water inlet and outlet temperature and also CO, HC, emission measured. It is conclude that decrease in BSFC with increase in Brake Power. Due to higher density, lower calorific value of ethanol, brake thermal efficiency of these fuel blends in sequence of D80B15E5, D70B20E10 & D70B25E5 are observed slightly higher for these blends in same sequence[49].

Biodiesel and ethanol have many advantages over regular diesel as renewable and domestically produced energy resources. Studies have shown that there is a substantial reduction of CO, unburned hydrocarbons and particulate matter emission, when they are used in conventional diesel engines

[Li et. al., 2005; Shi, et. al, 2005 and Srivastava, et. al, 2000].Agarwal, 2007, reported that ethanol diesel blends up to 20% can be used in the constant speed engines without any hardware modifications and leads to significant reduction in CO and NOx emission.

Kwanchareon, et al., 2006 studied the phase diagram of diesel–biodiesel–ethanol blends at different purities of ethanol and different temperatures. It was found that the fuel properties were close to the standard limit for diesel fuel; however, the flash point of blends containing ethanol was quite different from that of conventional diesel. The high cetane value of biodiesel could compensate for the decrease of the cetane number of the blends caused by the presence of ethanol. The heating value of the blends containing lower than 10% ethanol was not significantly different from that of diesel.

As for the emissions of the blends, it was found that CO and HC reduced significantly at high engine load, whereas NOx increased, when compared to those of diesel. Taking these facts into account, a blend of 80% diesel, 15% biodiesel and 5% ethanol was the most suitable ratio for diesohol production because of the acceptable fuel properties (except flash point) and the reduction of emissions.

Kim, Hwanam and Choi, Btungchul, 2008 investigated the exhaust gas characteristics and particulate size distribution of PM on a CRDI diesel engine using diesel, biodiesel and ethanol blends. They observed the reduced CO, HC, smoke emissions and total number of particles emitted, but increased NOx emissions.

Pang et al., 2006reported that the use of biodiesel-ethanol- diesel blend could slightly increase the emissions of carbonyls and NOx but significantly reduce the emissions of PM and THC. However preparation of stable blends of bio-diesel and ethanol is most frequently faced problem. To solve the problem, scientists have conducted several studies. The efforts have been made in this paper to present the general idea of work done in preparation of diesel – ethanol and ethanol – bio-diesel stables which could be used as alternate to convention diesel fuel.

We understand from the review of the literature, that biodiesel& Ethanol blended fuels can effectively reduce the environmental pollution without any major modification to the design of the engine. This study was to use Ethanol & biodiesel produced from linseed oil in diesel engine.

Finally test the performance of Ethanol & linseed biodiesel engine performance and pollution free emissions using of Ethanol &linseed biodiesel fuel [50].

2.2. Biodiesel

Biodiesel is non toxic & environmental friendly as it produces substantially less carbon monoxide and 100% less sulfur dioxide emissions with no un-burnt hydrocarbons and thus it is ideal fuel for heavily polluted cities. Biodiesel reduces serious air pollutants such as particulates and air toxicity. Due to its less polluting combustion, biodiesel provides a 90% reduction in Cancer risks and neonatal defects. Biodiesel has good potential for rural employment generation Just like petroleum diesel, bio-diesel operates in compression ignition engine; which essentially require very little or no engine modifications because bio-diesel has properties similar to petroleum diesel fuels. It can be stored just like the petroleum diesel fuel and hence does not require separate infrastructure. The use of bio-diesel in conventional diesel engines results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particulate matters. Bio-diesel is considered clean fuel since it has almost no sulphur, no aromatics and has about 10 % built- in oxygen, which helps it to burn fully. Its higher cetane number improves the ignition quality even when blended in the petroleum diesel. For new vehicles, a drastic reduction in sulphur content (< 350 ppm) and higher cetane number (>51) will be required in the petroleum diesel produced by Indian Refineries. Bio-diesel meets these two important specifications and would help in improving the lubricity of low sulphur diesel. The present specification of flash point for petroleum diesel is 50°C which is lower than all the countries in the world (>55°C). Bio-Diesel will help in raising the flash point, a requirement of safety. B20 (a blend of 20 percent by volume bio-diesel with 80 percent by volume petroleum diesel) has demonstrated significant environmental benefits with a minimum increase in cost for fleet operations and other consumers. Bio-diesel is registered as a fuel and fuel additive with the US Environmental Protection Agency and meets clean diesel standards established by the California Air Resources Board. Biodiesel is a non petroleum based diesel fuel which consists of the mono alkyl esters of

long chain fatty acids derived from renewable lipid sources. Biodiesel is typically produced through the reaction of a vegetable oil or animal fat with methanol in the presence of a catalyst to yield glycerin and biodiesel (chemically called methyl esters). Biodiesel is registered with the US Environmental Protection Agency as a pure fuel or as a fuel additive and is a legal fuel for commerce. Biodiesel is an alternative fuel which can be used in neat form, or blended with petroleum diesel for use in compression ignition (diesel) engines.

2.2.1. Types of biodiesels

There are different types of biodiesel which are derived from agriculturally cropped in different methods or from a different source of raw materials, such as; fuel from linseed, cotton seed oil, sunflower oil, jatropha oil, soybean, palm oil, seem seed and so on. From those, we are interested on biodiesel from linseed. Biodiesel fuel can be made from new or used vegetable oils and animal fats. Unlike fossil diesel, pure biodiesel is biodegradable, nontoxic and essentially free of sulphur and aromatic.

Biodiesel from linseed:-Linseed is an important oilseed and fiber crop grown for its seed as well as which is used to manufacture linen. Global output of linseed is estimated around 2.60 million ton per year with Canada, China, U.S and India on the top of the list. Canada, the leading producer, accounts for 80% of the global trade in linseed. India is the third largest producer of linseed. In India, linseed is mainly cultivated as a rabi crop which is sown during October–November and harvested in February–April. Linseed oil mercilessly extracted from the linseed constitutes 35% on oil content in the seeds.

Global production of linseed oil is estimated from 600,000 to 700,000 ton. Linseed is a cool season crop. Its cultivation is confined to low elevations, but it can be successfully grown up to 770 meters. Areas with the annual rainfall ranging from 45–75 cm are best suited for its cultivation.

Biodiesel is produced from linseed oil through a process called transesterification, with this process the higher fatty acids are separated to methyl and ethyl esters using methanol and catalyst KOH**.**

Linseed oil is a triglyceride. It is converted into ester using transesterification reaction. The reaction requires heat and a strong catalyst (alkalis, acids, or enzymes) to achieve complete

conversion of the vegetable oil into the separated esters and glycerin. The reaction is shown in below.

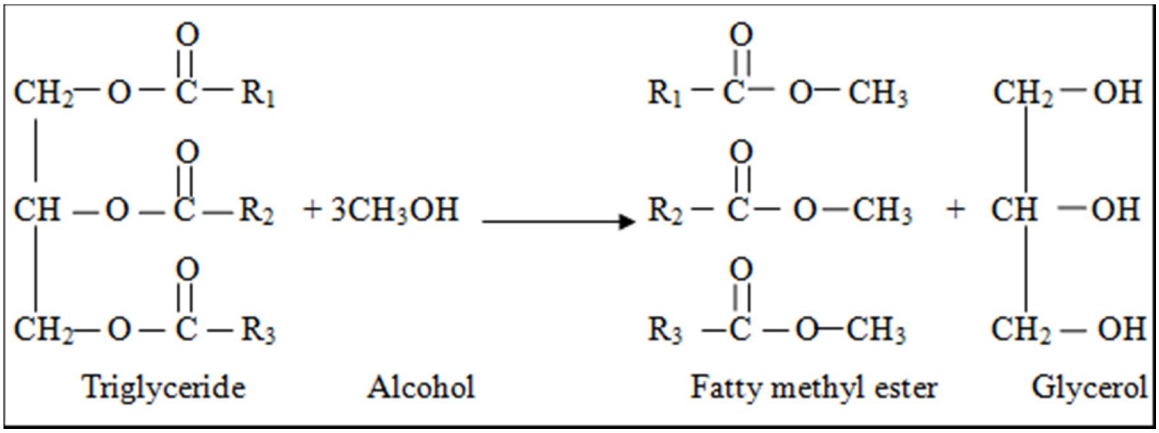


Figure 2.1 The reaction required heat and strong catalyst

In transesterification reaction the triglyceride molecule of the linseed oil reacts with methanol or ethanol in the presence of a catalyst such as sodium hydroxide (NaOH). The methanol used would react with the triglyceride molecule of the linseed oil and would result in an ester (biodiesel) and glycerin (by product).One molecule of linseed oil would require three molecules of alcohol and would result in an ester and a glycerin molecule. This reaction can also be called as base catalyzed transesterification reaction as the reaction would take place in the presence of a base catalyst. Ethanol as an attractive alternative fuel is a renewable bio-based resource and it is oxygenated, thereby providing the potential to reduce particulate emissions in compression-ignition engines.

2.2.2. Environmental considerations Promise of biodiesel: - linseed, diesel& Ethanol

Biodiesel fuels are produced from vegetable oil like linseed & diesel by using methanol and catalyst KOH. The combustion of biodiesel has been reported to emit lesser pollutants compared to diesel. It is found that by using biodiesel & ethanol, CO_2, HC and CO emissions decreases as the blend content increases & relatively the NOx emissions increases as the blend content increases. Eco friendly In view of environmental considerations, biodiesel produced from linseed oil& ethanol is suitable.

2.2.3. Advantages of biodiesel fuel

In IC engine, the thermal energy is released by burning the fuel in the engine cylinder. The combustion of fuel in IC engine is quite fast but the time needed to get a proper air/fuel mixture depends mainly on the nature of fuel and the method of its introduction into the combustion chamber.

The biodiesel fuel has the following advantages:

- It is a renewable substitute for petroleum and diesel fuel.
- It has low sulphur and aromatic content.
- It is readily available and biodegradable fuel.
- It has higher flash point than diesel.
- Its combustion efficiency is high.
- It has better lubricity properties than diesel.
- It has lower HC, CO2, CO emissions as compared to petroleum and diesel fuel.
- It has less particulate emissions than petroleum and diesel fuel.

The combustion process in the cylinder should take as little time as possible with the release of maximum heat energy during the period of operation. Longer operation results in the formation of deposits which in combination with other combustion products may cause excessive wear and corrosion of cylinder, piston and piston rings. The combustion product should not be toxic when exhausted to the atmosphere. These requirements can be satisfied using a number of liquid and gaseous fuels. The biodiesel from non edible sources like Jatropha, Pongamia, Mahua, Neem etc. meets the above engine performance requirement and therefore can offer perfect viable alternative to diesel oil.

2.2.4 Disadvantage of biodiesel fuel

One of the problems encountered when using biodiesel is the increase in nitrogen oxides emissions which can result in the formation of smog and acid rain. Similarly, biodiesel when compared to petro-diesel have a lower energy output. In order to produce the same amount of energy, more biodiesel required than petro-diesel. Also, the use of valuable cropland to grow biodiesel crops could result to a rise in cost of food and furthermore leads to food scarcity [4].

- Lower volatility [5].
- It has higher viscosity and low energy content than diesel
- Some of the problems with biodiesel are also injector coking, engine compatibility

2.2.5. Blending and storage

Biodiesel produced in the laboratory or available in market is used for the preparation of its blends with petroleum diesel by blending techniques. Take Biodiesel and petroleum diesel in a conical flask under continuous stirring to ensure uniform mixing at 45 ˚C for 45 to 60 minute. These blends are on volume basis and store in amber glass bottles at room temperature, making sure that appropriately stored and leave them for some days or months without movement for observation of phase separation etc. Tests are done and blended by skilled fully with professional understanding. [54,55]

2.2.6. Fuel Blend and Properties of Biodiesel

Biodiesels are characterized by their viscosity, density, cetane number, cloud and pour points, distillation range, flash point, ash content, sulfur content, carbon residue, acid value, copper corrosion, and higher heating value (HHV). The most important parameters affecting the ester yield during the trans-esterification reaction are the molar ratio of alcohol to vegetable oil and reaction temperature. The viscosity values of vegetable oil methyl esters decrease sharply after trans-esterification. The flash point values of vegetable oil methyl esters are significantly lower than those of vegetable oils. There is high regression between the density and viscosity values of vegetable oil methyl esters. The relationships between viscosity and flash point for vegetable oil methyl esters are considerably regular [6].

Table 2.1 Properties of biodiesel fuels

No	Property	ASTM standards	Diesel	Linseed biodiesel	Ethanol
1	Calorific Value, KJ/Kg	>33000	42,000 kJ/kg	38,896.2kJ/kg	268432kJ/kg
2	Flash Point, ^{0}C	>130	78^{0}C	154^{0}C	17
3	Fire Point^0 C	>53	83^{0}C	160^{0}C	34
4	Viscosity, cSt	1.9-6.0	2.049	4.336	1.2
5	Density, Kg/m^3	820-845	819kg/m^3	875.8 kg/m^3	789
6	Cloud point, ^{0} C	-3 to 12	<10	-2	-7
7	Pour point, ^{0} C	-15 to 10	-6	-6	<-35
8	Carbon residue %	<0.05	0.0214	0.0179	
9	Ash content %	0.02 Max	0.02	0.02	
10	Cetan index		57	52	8

The following discussions are reviewed for blended fuel properties:

A. Density

Density is a fuel property which has direct effect on the engine performance characteristics (Sandu & Chiru, 2007). Many fuel properties such as cetane number and heating value are related to density. Fuel density influences the efficiency of fuel atomization and combustion characteristics (Sandu & Chiru, 2007). Because diesel fuel injection systems meter the fuel by volume, the change of the fuel density will influence the engine output power due to a different mass of injected fuel. Ethanol density is lower than diesel fuel density, but biodiesel density is higher. It decreases with an increase in the % of ethanol in the blends as ethanol has less density. But, when the biodiesel percentage increases, the density increases , resulting in higher viscosity leads to inferior fuel injection. However density values for stable range of blends were in acceptable standards.

B. Cetane Index

Cetane Index of biodiesel is higher when compared to cetane index of diesel. But cetane index of ethanol is very less. Hence the cetane index of blends decreases with increase in percentage of ethanol. But as a percentage of biodiesel is constant at 60% it enhances the cetane index of blends. The blends containing less than 10% of ethanol are having higher cetane index than that of diesel and the blends with higher percentage of ethanol are having cetane index within the

acceptable limits of standard specifications. The cetane index of the blends decreases, with the increase of ethanol % because ethanol has low cetane index 5–8. The lower cetane index leads to poorer ignition property. However, biodiesel, improve this property as it has high cetane index. Some of the fuel blends (D85% B10% E 5%) have higher cetane index than diesel So that better engine performance can be obtained.

C. Heat of combustion

The heat of combustion decreases with the addition of ethanol and biodiesel in diesel, it is due to the lower calorific value of biodiesel and ethanol. These trends are reported by Fernando and Hanna, Cheenkachorn al., and Ajav and Akingbehin. Lower heating value of fuel blend has a direct influence on the specific power output of an engine. It is reviewed that the heat of combustion of the blends containing ethanol upto10% have heating value equivalent to conventional diesel.

D. Cloud and Pour Point

The cloud point of fuel when compared to cloud point of blends with increased percentage of ethanol is less but the pour point of biodiesel is higher than diesel due to increase in viscosity at reduced temperatures which ceases the oil to flow. However the presence of ethanol in the blends affected the pour point. Blends with less than 10% of ethanol were found to have minimum variations in pour points as the percentage of biodiesel is constant. Blends with 12%, 14%, 16%,18% and 20% of ethanol found to have lower pour points due to the fact that the ethanol delayed the degree of coalescent of the blends despite of miscibility of ethanol, biodiesel and diesel.

All of the blends have almost the same pour point at30˚C and above up to 40˚C. Because the ethanol has a very low pour point and biodiesel has a higher pour point than diesel. But in the blends diesel is a major component, hence, the pour points of the blends and base diesel have not much difference.

E. Flash point and Fire Point

As biodiesel is produced from acid oil and fatty acids of acid oil are of higher molecular weights (250 to 300) they are non volatile. They give out sufficient vapors at elevated temperatures to

form a combustible mixture with air hence flash and fire points of biodiesel are much higher than diesel and ethanol №. As the flash and fire points of ethanol are very less when compared to diesel and biodiesel, the flash and fire points of the blends decreases with increase in percentage of ethanol. But as the percentage of the biodiesel in blends is higher i.e., 60%, with 20% of ethanol, the flash and fire points of the blends are slightly lower than the flash and fire points of the conventional diesel which makes it as a convenient fuel as that of diesel. It is the lowest temperature at which a fuel ignites before ignition source.

F. Kinematic Viscosity: Viscosity is one of the most important fuel properties. The viscosity has effects on the atomization quality, the size of fuel drop, the jet penetration and it influences the quality of combustion (Sandu & Chiru, 2007). Fuel viscosity has both an upper and a lower limit. It must be low enough to flow freely at its lowest operational temperature. Too low viscosity can cause leakage in the fuel system. High viscosity causes poor fuel atomization and incomplete combustion, increases the engine deposits, needs more energy to pump the fuel and causes more problems in cold weather because viscosity increases as the temperature decreases. Viscosity also affects injectors and fuel pump lubrication (Sandu & Chiru, 2007).The surface tension of the fuel is an important parameter in the formation of droplets and fuel's combustion. A high surface tension makes the formation of droplets from the liquid fuel difficult. The viscosity of the blends decreases as the percentage of ethanol in the blend increases. This is mainly due to very low viscosity of the ethanol when compared to viscosities of biodiesel and diesel.

G. Calorific Value

Calorific value of the fuel is one of the most important properties as it has a direct influence on power output of an engine. The results show that calorific value of mixture of diesel and biodiesel decreases with increase in ethanol percentage. However heating values of blends containing less than 10% of ethanol were not much different from that of conventional diesel and the calorific value of tested fuel blends were quite high so that better combustion characteristics can be obtained when compared to other vegetable oils [7, 8].

2.2.7. Fuel quality

The quality of fuel used for in any motor vehicle engine is very important to its long life and the correct operation. But, if the fuel is not an appropriate or affects by temperature which is changes

to from liquid to vapor incorrectly, drivability will be affected. Biodiesel is the name given to a variety of ester-based oxygenated fuels made from linseed oil, other vegetable oils, or animal fats. Because of having high viscosity and volatility of biodiesel, uses such method called transesterification, which gives for the purpose of reducing the viscosity and volatility. As a result, Esters have lower viscosities than the parent oils (linseed oil). Accordingly, this maintains the quality of linseed biodiesel fuel in improving the injection process and ensures better atomization of the fuel in the combustion chamber. Biodiesel has been used not only as an alternative fuel, but also an additive for diesohol [Fernando, et al., 2004 and Cheenkachorn, et al, 2004. Fernando, et al., 2004 investigated the advantages of using oxygenated diesel fuel blend over regular diesel. It was reported that oxygenations significantly reduced particulate matter (pm) and toxic gases such as CO, sulfur oxides (SOx).

2.2.8. Effects of fuel quality

Biodiesel is an alternative fuel for diesel engines. The results show that compared to diesel fuel, all of the vegetable oils are much more viscous, are much more reactive to oxygen, and has higher cloud point and pour point. They also found that compared with diesel fuel, vegetable oils and their biodiesels offer lower engine noise, and lower smoke, HC, and CO, slightly higher NOx and higher thermal efficiency. The use of ethanol in diesel can reduce particulate matter (PM) emissions for motor vehicles. Barabas et al., 2010, D85/B10/E5 D80/B10/E10 and D70/B25/E5 blends were compared to diesel fuel. And 10% biodiesel & 5% Ethanol blend with 85% diesel volume basis fuel offers better engine performance and lower emission.

2.2.9. Use of different blends of biodiesel &Ethanol

The use of blending of linseed oil & Ethanol with conventional diesel in proportions is for the purpose of having suitable blending of a linseed biodiesel & ethanol in compression ignition engines. In general, the different blending percentages gives in reduction of emissions and lower engine noise in improving performance of linseed biodiesel & ethanol at which proportion of blend does acceptable and which blend does meets to have same properties with conventional fuel and linseed to diesel blend is the best .

2.2.10. Engine Performance with linseed oil and ethanol

As literature reported the study of kinetics and simulation of alkali-catalyzed trans-esterification of linseed oil in a batch reactor they compared the properties of non-edible oils and biodiesel

produced with that of mineral diesel. They observed that due to transesterification process there was a significant decrease in kinematic viscosity of vegetable oils, Due to the improvement in the other properties of biodiesel with the transesterification process they stated that the biodiesel derived from non-edible vegetable oils could prove to be a suitable alternative fuel for diesel.
The performance and emission parameters of variable compression ratio engine fueled with three different blends of optimized linseed biodiesel (10 %, 15 % & 20 % were compared with those of diesel& linseed oil 10 % , ethanol 5% blend diesel 85% have better performance and other parameters.

2.2.11. Sources of biodiesel raw materials

Typical raw materials of biodiesel are rapeseed oil, canola oil, soybean oil, sunflower oil and palm oil. Beef and sheep tallow and poultry oil from animal sources and cooking oil are also sources of raw materials. There are various other biodiesel sources: almond, andiroba (Carapa guianensis), babassu (Orbignia sp.), barley, camelina (Camelina sativa), coconut, copra, cumaru (Dipteryx odorata), Cynara cardunculus, fish oil, groundnut, Jatrophacurcas, karanja (Pongamia glabra), laurel, Lesquerella fendleri, Madhuca indica, microalgae (Chlorella vulgaris), oat, piqui (Caryocar sp.), poppy seed, rice, rubber seed, sesame, sorghum, tobacco seed, and wheat [9].

Vegetable oils are renewable fuels. They have become more attractive recently because of their environmental benefits and the fact that they are made from renewable resources. Vegetable oils are a renewable and potentially inexhaustible source of energy, with energy content close to that of diesel fuel. Global vegetable oil production increased from 56 million tons in 1990 to 88 million tons in 2000, following a below-normal increase. The source of this gain was distributed among the various oils. Global consumption rose 56–86 million tons, leaving world stocks comparatively tight [10].

A variety of biolipids can be used to produce biodiesel. These are (a) virgin vegetable oil feedstock; rapeseed and soybean oils are most commonly used, though other crops such as mustard, palm oil, sunflower, hemp, and even algae show promise; (b) waste vegetable oil; (c) animal fats including tallow, lard, and yellow grease; and (d) non-edible oils such as Jatropha, Neem oil, castor oil, and tall oil [11]. Various oils have been in use in different countries as raw materials for biodiesel production owing to its availability. Soybean oil is commonly used in United States and rapeseed oil is used in many European countries for biodiesel production,

whereas, coconut oil and palm oils are used in Malaysia and Indonesia for biodiesel production [12–14]. In India and south east Asia, the Jatropha tree (Jatropha cursas) [15], Karanja (Pongamia pinnata) [12, 16, 18] and Mahua (M. indica) [11] is used as a significant fuel source. Commonly accepted biodiesel raw materials include the oils from soy, canola, corn, rapeseed, and palm.

New plant oils that are under consideration include mustard seed, peanut, sunflower, and cotton seed. The most commonly considered animal fats include those derived from poultry, beef, and pork [18]. Rapeseed has been grown in Canada since 1936. Hundreds of years ago, Asians and Europeans used rapeseed oil in lamps. Cottonseed oil is used almost entirely as a food material. Sesame, olive, and peanut oils can be used to add flavor to a dish. Walnut oil is high-quality edible oil refined by purely physical means from quality walnuts. Algae can grow practically anywhere where there is enough sunshine. Some algae can grow in saline water. All algae contain proteins, carbohydrates, lipids and nucleic acids in varying proportions. While the percentages vary with the type of algae, there are algae types that are comprised up to 40% of their overall mass by fatty acids [19].

The most significant distinguishing characteristic of algal oil is its yield and hence its biodiesel yield. According to some estimates, the yield (per acre) of oil from algae is over 200times the yield from the best-performing plant/vegetable oils [20]. Microalgae are the fastest-growing photosynthesizing organisms. They can complete an entire growing cycle every few days.

Approximately 46 tons of oil/hectare/year can be produced from diatom algae. Different algae species produce different amounts of oil. Some algae produce up to 50% oil by weight.

The production of algae to harvest oil for biodiesel has not been undertaken on a commercial scale, but working feasibility studies have been conducted to arrive at the above number. Specially bred mustard varieties can produce reasonably high oil yields and have the added benefit that the meal left over after the oil has been pressed out can act as an effective and biodegradable pesticide [11].

Table 2.2 ASTM standards of biodiesel and petro diesel fuels

Property Test method	ASTMD975(Petro diesel	ASTMD6751(biodiesel,B100)	
Flash point	D93	325 K min	403 K
Water and sediment	D2709	0.05 max %vol	0.05 max %vol
Kinematic viscosity(at313K)	D445	1.3-4.1$mm^{2/5}$	1.9-6.0$mm^{2/5}$
Sulfated ash	D874	-	0.02max%Wt
Ash	D482	0.01max%Wt	-
Sulfur	D5453	0.05max%Wt	-
Sulfur	D2622/192	-	0. 05max%Wt
strip corrosion	D130	No,3max	No,3max
Cetane number	D613	40 min	47min
Aromaticity	D1319	35max%Wt	-
Carbon residue	D4530	-	0. 05max%mass
Carbon residue	D524	0.35max%mass	-
Distillationtemp(90%volume recycle)D1160		555Kmin-611Kmax	-

Table 2.3ASTM standards of biodiesel and petro diesel fuels

Fuel Type	Availability	
	Current	Future
Gasoline	Excellent	Moderate-poor
Biodiesel	Moderate	Excellent
Compressed natural gas (CNG)	Excellent	Moderate
Hydrogen fuel cell	Poor	Excellent

2.2.12. International biodiesel standards

The European Committee for Standardization (CEN) is responsible for standardization on a European level. CEN is currently finalizing a biodiesel fuel quality standard for Fatty Acid Methyl Ester (FAME) for use as fuel for diesel engines. The standard is currently in draft form and titled pr EN 14214 – Automotive fuels – Fatty acid methyl esters (FAME) for diesel engines

Requirements and test methods. If the draft becomes a European standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. If accepted the standard will specify the requirements and test methods for marketed and delivered biodiesel to be used as either automotive fuel for diesel engines (100% - sole diesel engine fuel – B100) or as an extender for automotive fuel for diesel engines in accordance with the requirements of EN 590 (the CEN diesel standard). At 100% concentration it is applicable to fuel for use in diesel engine vehicles designed or subsequently adapted to run on 100% FAME. An amendment to EN 590 was issued to allow a 5% incorporation of biodiesel into diesel fuel.

There are currently several national biodiesel standards in European countries such as Germany, Austria and France. Of these, the German DIN 51606 standard is one of the best developed and most stringent.

In the US a standard for biodiesel (American Society for Testing and Materials -ASTM D 6751 – Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels) was finalized in May 2002. The standard does not include the same number of parameters as prEN 14214 but the parameters that coincide have similar limits. The specification covers low sulfur biodiesel (B100) for use as a blend component with diesel fuel oils defined by ASTM D 975 Grades 1-D, 2-D, and low sulfur 1-D and 2-D.

The ASTM D 6751 standard includes information on biodiesel blends and states that a considerable amount of experience exists in the US with 20% blend of biodiesel, primarily produced from soybean oil. In the US 99% of biodiesel is used in blends of 20% or less (approximately 24% as B5/B2, 75% as B20 and 1% as B100). Although B100 can be used, it is recommended that blends of over 20% should be evaluated on a case by case basis until further experience is available. The standard also advises that the Fuel Injection Equipment (FIE) manufacturers should always be consulted regarding the application limits of their products.

2.2.13. The case for a national biodiesel standard

A national biodiesel standard would specify parameters to ensure consistency in biodiesel quality, thus ensuring the availability of fuel that:

- ✓ Reduces the level of pollutants and emissions arising from the use of fuel they may cause environmental and health problems;
- ✓ Facilitates the adoption of better vehicle and emission control technologies;
- ✓ Allows more effective operation of engines; and
- ✓ Consistently meets consumer expectations.

2.2.14. Biodiesel based fuels

A significant amount of discussion within the industry has occurred regarding the concentration of biodiesel used in blends with diesel and the resulting impact on the specification.

Biodiesel is completely miscible with both US Grade No.1-D and 2-D fuel. It can be used as a 100% replacement for diesel, or as a blending stock. At 2002 world market prices for crude petroleum oil and animal fats and vegetable oils, the cost of biodiesel is more than diesel. Therefore, applications for biodiesel are primarily those where it can provide value added benefits (emissions, biodegradability, lubricity, etc.) or those where it represents a cost competitive option to meet legislative initiatives (alternative fuels, greenhouse gas reduction, economic development, etc.) for which diesel is not an option.

Most of the experience with biodiesel in the US has been with 20% blends of biodiesel with 80% diesel. The market share is approximately 75% B20, 24% B5/B2 and 1% B100). This appears to be a compromise between emissions reduction and cost, and also minimizes cold weather impacts. There are additional markets, however, which are using 100% biodiesel such as in marine applications where the biodegradability of pure biodiesel is important.

It is also anticipated that in the US biodiesel, when used as a blend with diesel, will most likely be produced by someone other than the seller of the finished blend. This also creates a need for a standard for pure biodiesel before blending. The standard adopted by ASTM, therefore, is for the pure (or 100%) biodiesel. The rationale is that if biodiesel conforms to the pure standard then it can be blended with diesel in any proportion. Since most experience in the US has been with a 20% blend of biodiesel with 80% diesel, engine manufacturers have requested a caveat be added

to the specification that blends over 20% be evaluated on a case by case basis by the engine manufacturer until more data become available

2.2.15. Biodiesel as a fuel additive

Additives are being investigated to control operability properties of biodiesel, such as cold flow and NOx emissions, as well as storage properties.

In most cases, the industry believes that blends up to 20% (B20) will cause no detriment to performance. B20 has proven to be a practical fuel that can be used in any diesel engine with few precautions or changes. However, most US auto, engine and fuel injection equipment companies strongly discourage the use of blends over 20%, mainly due to the possible impacts of higher blends on equipment and fuel systems that have not been thoroughly tested. There are additional concerns regarding the influence of the increased biodiesel content greater than 20% on cold flow properties, material compatibility, maintenance intervals, fuel stability, biological growth, energy content, emissions and overall handling [21]

2.2.16. Blending biodiesel with petroleum diesel

Vegetable oil can be directly mixed with diesel fuel and may be used for running an engine. The blending of vegetable oil with diesel fuel were experimented success-fully by various researchers. A diesel fleet was powered with a blend of 95% filtered used cooking oil and 5% diesel in 1982. In 1980, Caterpillar Brazil Company used pre-combustion chamber engines with a mixture of10% vegetable oil to maintain total power without any modification to the engine. A blend of20% oil and 80%diesel was found to be successful [22]. It has been proved that the use of100% vegetable oil was also possible with some minor modifications in the fuel system. The high fuel caused the major problems associated with the use of pure vegetable oils as fuel viscosity in compression ignition engines. Micro-emulsification, pyrolysis and trans esterification are the remedies used to solve the problems encountered due to high fuel viscosity.

Blending biodiesel with petroleum diesel compensates for many cold flow problems through dilution. By blending to levels of up to 20% (B20), the use of additives becomes more practical and more effective. The use of #1 diesel, or kerosene, is also an option that many blenders use to help moderate the effects of cold weather. Testing different mixtures of the actual fuels to be

used is the best way to guarantee performance and to determine cost effectiveness. Our local distributor may also have some data or samples of "winterized" fuels.

Biodiesel may also need to be warmed prior to blending. To ensure successful blending into a single mixture, the biodiesel and petroleum diesel should be blended at similar temperatures. Blending products that are at extreme temperature differences will not promote homogeneity within the final blend. The B100 will lend itself to easier mixing with diesel when the biodiesel is at temperatures of at least 25-30° F above the reported Cloud Point [21].

2.2.17. Health, safety, and environmental benefits.

Proponents of biodiesel contend that it offers several health and environmental benefits relative to petroleum-based diesel: biodegradable; less carbon monoxide (CO) and sulfur oxides (SO2) emissions; less odor; less particulate or soot emissions in some engines; and safer handling due to a higher flash point.

In addition, biodiesel use may reduce CO2 (a greenhouse gas), oral and dermal toxicity, ozone precursors, and mutagenic and carcinogenic compounds associated with diesel exhaust.5 From their perspective, increased substitution of biodiesel for petroleum-based diesel fuel may offer the broader public greater

Any additional concerns in respect to safety and health, including first aid and firefighting measures, may be addressed within the Material Safety Data Sheets (MSDS) relevant to either soy-based or canola-based methyl esters produced by Archer Daniels Midland Company.

2.2.18. Possible Engine Problems When Using Biodiesel

Many problems have been reported by people using biodiesel fuel. Careful investigation indicates that most of these difficulties can be attributed to poor-quality biodiesel fuel and are almost identical to the problems caused by low-quality petroleum diesel. However, some of the problems (primarily cold-weather problems) are not due to poor fuel quality but are related to the inherent properties of biodiesel fuel. Fortunately, most of these problems can be avoided or minimized. Common engine problems when using biodiesel, their possible causes, and their solutions are presented below. This list is not meant to serve as an exhaustive repair manual but rather to give a sense of some of the performance issues related to biodiesel fuel.

Problem: Deposits on injectors affect fuel spray pattern. The most common symptoms are misfiring or hard starting. This is most likely caused by either cold-weather operation with partially solidified Fuel, or by fuel that was not completely transformed from oil to biodiesel. Vegetable oil has a tendency to form deposits on the injectors, especially when the engine is running at part load.

Solution*:* Have the injectors cleaned by a qualified mechanic—the precise nature of injectors makes these parts difficult to clean unless you have specialized training and equipment. Low-temperature flow-improving additives can be used to improve the fuel's operation in cold conditions and to help avoid this problem in the future. You should also check to make sure the fuel is free of contaminants and has been fully transformed from oil to biodiesel.

Problem*:* Deposits in injector pump (varnish and gums) affect performance. The most common symptoms are hard starting, decreased power, and misfiring. This can be caused either by biodiesel fuel that has been incompletely transformed, or by biodiesel fuel that has partially oxidized.

Solution*:* Have the injector pump cleaned by a qualified mechanic. As with the injectors, this job is not practical for the home mechanic due to the precise nature of the pump's components.

Problem: Lubrication oil becomes diluted, leading to rising oil levels, loss of oil pressure, and/or worn bearings. This is often due to excessive blow-by in the cylinder from a poor fuel spray pattern and/or worn rings.

Solution: Monitor your lubrication oil regularly, and take Corrective action if any signs of dilution occur.

Problem: Engine either refuses to start in cold weather or runs only a few seconds after starting. The filter has probably become clogged with particles of solidified biodiesel.

Solution: You could wait for springtime to arrive, or possibly try warming the fuel filter—12-volt jacket heaters are available.

"De-icier" additives for petroleum diesel can be used for biodiesel as well. If you live in a cold climate, you should consider either using an additive designed to improve the fuel's cold-weather Properties, or else install a "preheated" to warm up your fuel tank and filter. It may be necessary

to winterize your fuel by blending biodiesel with either kerosene or winter-grade petroleum diesel during the coldest months of the year. Experience at Penn State's farm has been that if tractors are stored in a warm garage (above freezing), they tend to start easily and operate well throughout the day, even when outdoor air temperatures are quite low.

Problem: Fuel leaking from fuel line. Biodiesel is a very effective solvent for some materials, including certain types of elastomeric (e.g., Buna Nitrile rubber).

Solution: Before using biodiesel fuel in your engine, confirm that the engine is "rated for biodiesel use," which means that the materials are all compatible with biodiesel fuel. Otherwise, you will need to locate all materials in the engine (i.e., seals and hoses) that can be degraded by biodiesel and replace them with biodiesel-rated components. This can be quite a chore. Usually, components that are made from "fluoroelastomers" (e.g., Viton or Teflon) can be considered safe for use in a biodiesel engine.

Problem: Fuel filter clogs, but not due to cold weather. There are three main possibilities: your biodiesel fuel quality is low, leading to formation of resins or gels in the fuel system; algae are building up in your tank; or the biodiesel is "scouring" older deposits out of the sludge that typically builds up in the bottom of old fuel tanks. Operators who switch from petroleum diesel to biodiesel are more likely to experience this problem since older vehicles that have used petroleum diesel for many years are likely to have quite a bit of deposits in the fuel tank.

Solution: If the problem is caused by low-quality fuel, correct this problem by using only ASTM-certified fuel. If the problem is caused by algae, an algaecide additive can be helpful. Also, simple measures such as filling your fuel tank at the end of the day can reduce moisture levels in the fuel and inhibit the growth of algae. If you are just switching to biodiesel after years of using petroleum diesel, you will need to change filters often at first, as the biodiesel loosens deposits from the inside of your fuel tank and engine.

In extreme cases, you may need to have your fuel tank thoroughly cleaned or replaced before adding the next tank of biodiesel.

2.2.19. Compatibility of diesel powered engines with biodiesel blends

Blend of 20%boidiesel and lower can be used in diesel equipment with no, or only minor modifications. Although biodiesel can be used in most diesel engines with no modifications to the engine or the vessel's fuel system, it is highly recommended that you check with your manufacturer before using it. Some problems have been associated with its use in the environment, and your engine manufacturer can give you further guidance as to what biodiesel blends are acceptable for use and how to moderate potential problems.

SOURCES:

American Petroleum Institute, www.api.org

Alternative Fuels and Advance Vehicles DataCenter, www.afdc.energy.gov/afdc/ethanol/

2.2.20. Performance Parameter of Engine Operation Using Biodiesel

2.2.20.1. Engine Performance

Biodiesel produces about 3-5% less engine power and torque due to its lower energy compared to diesel. It is expressed in terms of kWh/liter of fuel or as Brake specific fuel consumption (BSFC) in gm/kWh.

2.2.20.2. Deposit and Clogging

Deposits and clogging problems are widely reported and are generally attributed to substandard quality of biodiesel or due to its less oxidation stability and therefore engine wear is relatively more when run on biodiesel.

2.2.20.3. Pollution from engine exhaust:

Biodiesel results in much less air pollution due to its higher oxygen content and absence of "aromatic compounds" and sulphur. The NOx tends to be slightly higher compared to biodiesel which can be minimized by proper engine timing.

2.2.20.4. Cold-weather performance

Diesel engines operated in cold weather experience the problems of clogging of the filters and/or choking of the injectors. The use of flow improving additives and "winter blends" of biodiesel

and kerosene has proved effective in the operating range of climate temperatures B100 tends to operate well at temperatures down to about 5°C. Additives reduce the range by about 5-8°C, while the winter blends have proved effective at temperatures as low as -20°C or below.

2.2.21. Criteria for a fuel to be engine fuel

In IC engine, the thermal energy is released by burning the fuel in the engine cylinder. The combustion of fuel in IC engine is quite fast but the time needed to get a proper air/fuel mixture depends mainly on the nature of fuel and the method of its introduction into the combustion chamber. The fuel should therefore satisfy the following performance.

1. High energy density.
2. Good combustion characteristics.
3. High thermal stability.
4. Low deposit forming tendencies.
5. Compatibility with the engine hardware.
6. Good fire safety.
7. Low toxicity.
8. Less pollution.
9. Easy transferability and onboard vehicle storage.

The combustion process in the cylinder should take as little time as possible with the release of maximum heat energy during the period of operation. Longer operation results in the formation of deposits which in combination with other combustion products may cause excessive wear and corrosion of cylinder, piston and piston rings. The combustion product should not be toxic when exhausted to the atmosphere. These requirements can be satisfied using a number of liquid and gaseous fuels. The biodiesel from non edible sources like Jatropha, Pongamia, Mahua, Neem, linseed etc meets the above engine performance requirement and therefore can offer perfect viable alternative to diesel oil in India.

2.2.22. Performance of diesel engine with biodiesel fuel

Literature survey reveals that biodiesel perform satisfactorily during diesel engine operation. And B20 blend provides the fuel economy almost similar to the diesel. Due to its high lubricity, it causes less wear and tear to engine part. Numerous studies have are reported on the

performance and emission of CI engines, fuelled by B100 biodiesel as well as its blends with diesel. It oxygenated nature leads to more complete combustion, resulting in lower emission due to higher combustion temperature. The following parameters are used to evaluate the performance of diesel engine using biodiesel and its blends:

2.2.22.1 Brake Mean Effective Pressure (BMEP)

It is an important parameter for comparing the performance of different fuels and defined as the average pressure the engine can exert on the piston through one complete operating cycle. It is the average pressure of the gas in the fuel mixture inside the engine cylinder based on net power. BMEP is independent of the RPM and size of the engine.

2.2.22.2 Brake Horsepower (BHP)

It is the measure of an engine's horsepower before the loss in power caused by the gearbox, alternator, water pump, and other auxiliary components like power steering pump, muffled exhaust system, etc. Brake refers to a device used to load an engine and hold it at a desired RPM. During testing, the output torque and rotational speed can be measured to determine the brake horsepower which is the actual shaft horsepower and is measured by the dynamometer by :

BHP = IHP-FP

Where BHP is brake horse power and IHP is indicated horse power while FP is frictional power the indicated power is produced from the fuel inside the engine while some power is lost due to friction the remaining power available at the shaft of the engine is brake horse power.

2.2.22.3 Mechanical Efficiency

Part of the indicated work per cycle is used to expel exhaust gases, induct fresh air, and also overcome the friction of the bearings, pistons, and other mechanical parts of the engine. The mechanical efficiency is the measure of the ability of the engine to overcome the frictional power loss and can be defined as

$$\text{Mechanical Efficiency} = \frac{\text{work output}}{\text{work input}}$$

The work output is also defined as brake horse power and input is indicated horse power and the ratio of BHP to IHP is defined as mechanical efficiency.

2.2.22.4 Brake Specific Fuel Consumption (BSFC)

The BSFC defined as the fuel flow rate per unit of power output is a measure of the efficiency of the engine in using the fuel supplied to produce work. It is desirable to obtain a lower value of BSFC meaning that the engine used less fuel to produce the same amount of work. It can be calculated by BSFC (g/kWh) =Wf /Pb Where, Wf = fuel consumed (g/h) Pb = brake power (kW) which can be calculated by: Pb = Pg/g Where, Pg = load (kW) g = efficiency numerous, authors [23,24,25,26,27] have performed the experiment on the diesel engine to increase the BSFC using various blends of biodiesel from various resources including diesel.

2.2.22.5 Brake Thermal Efficiency (BTE)

It is the ratio of the thermal energy in the fuel to the energy delivered by the engine at the crankshaft. It greatly depends on the manner in which the energy is converted as the efficiency is normalized respect to the fuel heating value. It can be expressed by:

BTE (b) = Pb/(mf x NCV) Where, Pb = brake power (kW) mf = fuel consumption (kg/sec) NCV = net calorific value (kJ/kg) BTE has also been determined by various workers [28,29] using biodiesel as fuel and it is found that there is no significant change in the thermal efficiency while using biodiesel up to B20 but there is a slight decrease in thermal efficiency when B100 was used which is due to the lower energy content of biodiesel. The brake thermal efficiency of the engine fuelled with the DBE5% and DBE10% blends were higher but decreases as the ethanol concentrations increased compared with diesel fuel.

2.2.23. Engine Performance with linseed biodiesel

Properties of diesel and linseed is more equal when compare to the other edible oil and the linseed's properties is closely similar to the diesel and also the effect of linseed oil in the performance section is good when compare to the other oils. The HC and CO emission are considerably decreased when the linseed oil was used. The NOX only increases when linseed increases. The linseed oil has flash and fire points similar to diesel. It can be possesses good calorific value. It can be easily mixed with diesel. It has the density similar to diesel.

Linseed oil consists of primarily of the mixed glycerides of Oleic acid, Linoleic acid and Linolenic acid. The kinematic viscosity of Linseed oils varies in the range of 26-30 mm2/s at

40ºC. The high viscosity is due to their larger molecular mass and chemical structure. Vegetable oils have high molecular weights of 600-900, which are three or more times higher than that of diesel fuel. The flash point of linseed oil is also very high (about 222ºC). The auto-ignition temperature is about 343ºC. Specific gravity is 0.93 and density 931 kg/m3. Calorific value is about 40 MJ/kg, comparatively lower than that of diesel fuels (about 45 MJ/kg). This is because the presence of chemically bonded oxygen in vegetable oils lowers the heating value by about 10%. The cetane number is in the range of 32-40, while the iodine value ranges from 0-200, depending on un saturation. The cloud and pour point of vegetable oils is higher than that of diesel fuel [33, 34].

2.2.24. Biodiesel cost

Biodiesel can be blended and used in many different concentrations. The most common are: B20 (6% to 20% biodiesel blended with petroleum diesel), B5 (5% biodiesel, 95% petroleum diesel) and B2 (2% biodiesel, 98% petroleum diesel). B100 (pure biodiesel) is typically used as a blend stock to produce B5 and B20 and rarely used as a transportation fuel.

Low-Level Blends

ASTM International develops specifications for a wide variety of products, including conventional diesel fuel (ASTM D975). This specification allows for biodiesel concentrations of up to 5% (B5) to be called diesel fuel, with no separate labeling required at the pump. Low-level biodiesel blends, such as B5 are ASTM approved for safe operation in any compression-ignition engine designed to be operated on petroleum diesel. This can include light-duty and heavy-duty diesel cars and trucks, tractors, boats, and electrical generators.

B20

B20 is a common biodiesel blend in the United States. B20 is popular because it represents a good balance of cost, emissions, cold-weather performance, materials compatibility, and ability to act as a solvent. Most biodiesel users purchase B20 or lower blends from their normal fuel distributors or from biodiesel marketers. Regulated fleets that use biodiesel blends of 20% (B20) or higher qualify for biodiesel fuel use credits under the Energy Policy Act of 1992 .B20 must meet prescribed quality standards as specified by ASTM D7467 (summary of requirements).

The Department of Energy's Vehicle Technologies Office previously supported work to test and improve biodiesel quality, helping more fuel meet ASTM standards.

B20 and lower-level blends generally do not require engine modifications. Engines operating on B20 have similar fuel consumption, horsepower, and torque to engines running on petroleum diesel. B20 with 20% biodiesel content will have 1% to 2% less energy per gallon than petroleum diesel but most B20 users report no noticeable difference in performance or fuel economy. Biodiesel has some emissions benefits, especially for engines manufactured before 2010. For engines equipped with selective catalytic reduction (SCR) systems, the air quality benefits are the same whether running on biodiesel or petroleum diesel. However, biodiesel still offers better greenhouse gas (GHG) benefits compared to conventional diesel fuel. The emissions benefit is roughly commensurate with the blend level; that is, B20 would have 20% of the GHG reduction benefit of B100.

However, not all diesel engine manufacturers cover B20 use in their warranties Users should always consult their vehicle and engine warranty statements before using biodiesel.

B100 and High-Level Blends

B100 and other high-level biodiesel blends are less common than B20 and lower blends due to a lack of regulatory incentives and pricing. B100 can be used in some engines built since 1994 with biodiesel-compatible material for certain parts, such as hoses and gaskets. B100 has a solvent effect, and it can clean a vehicle's fuel system and release deposits accumulated from petroleum diesel use. The release of these deposits may initially clog filters and require frequent filter replacement in the first few tanks of high-level blends.

When using high-level blends, a number of issues should be considered. The higher percentage of biodiesel above 20%, the lower the energy content per gallon. High-level biodiesel blends can also impact engine warranties, gel in cold temperatures, and may present unique storage issues. B100 use could also increase nitrogen oxides emissions, although it greatly reduces other toxic emissions.

B100 requires special handling and may require equipment modifications. To avoid engine operational problems, B100 must meet the requirements of ASTM D6751, Standard

Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels (summary of requirements

The Ethiopian Government announced major changes in 2006 to move the fuel taxation system towards greater taxation neutrality between vehicle fuels. Biodiesel and other alternative fuels will continue to enjoy a significant excise advantage (50 per cent of the excise rate on an energy equivalent basis) compared to petroleum-derived diesel from July1, 2003 to July1, 2007, excise on biodiesel will be increased in five equal annual installments to 9.1 cents per liter, resulting in biodiesel having an ultimate excise benefit of 9.043 cents per liter in a B5 blend this represents an excise advantage of just over 1 cent per liter.

Data source

National Biodiesel Board's OEM Information for those that support the use of biodiesel blends).

2.2.25. Transesterification of reaction

Transesterification: Transesterification (also called alcoholyis) is the reaction of a fat or oil with an alcohol to form esters and glycerol. A catalyst is usually used to improve the reaction rate and yield. Because the reaction is reversible, excess alcohol is used to shift the equilibrium to the products side.

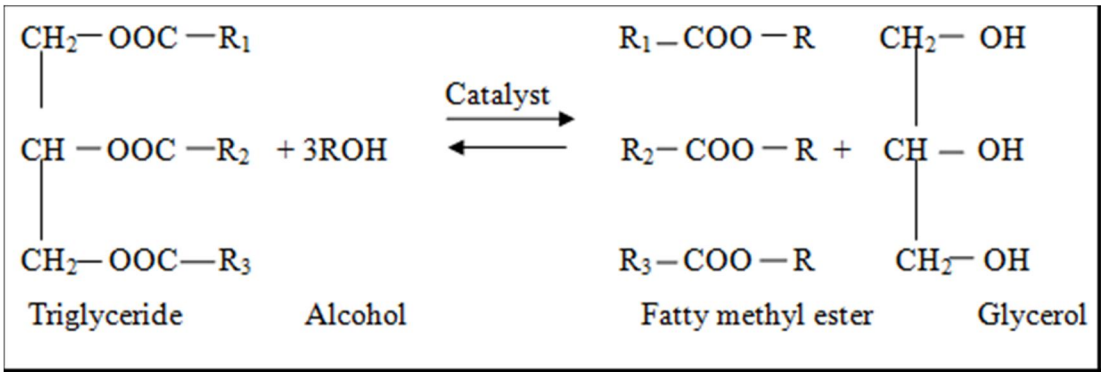


Figure 2.2.Transesterification reaction [30]

The alcohols which are used in this process are methanol, ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are used most frequently, especially methanol because of its low cost and its physical and chemical advantages. Methanol can quickly react with the triglycerides and the catalyst like NAOH is easily dissolved in it. Generally to complete a transesterification stoichiometrically, a 3:1 molar ratio of alcohol to triglycerides is needed. In practice, the ratio needs to be higher to drive the equilibrium to a maximum ester yield. The reaction can be

catalyzed by alkalis, acids, or enzymes. The alkalis include NaOH, KOH, carbonates and corresponding sodium and potassium alkoxides such as sodium methoxide, sodium ethoxide, sodium propoxide and sodium butoxide. Sulfuric acid, sulfonic acids and hydrochloric acid are usually used as acid catalysts. Lipases also can be used as biocatalyst [31]. Alkali-catalyzed transesterification is much faster than acid-catalyzed transesterification and is most often used commercially. This process raised the cloud point and pour point. This process is use with oils having less fatty acid content. This process is generally preferred over all other process for the biodiesel production

2.3. Linseed production an over view

Linseed oil also known as flaxseed oil. Linseed oil is a rich source of linoleic acid (40-60%).The

Climatic and soil conditions of India are convenient for the production of linseed crop. At present

Linseed is cultivated in about 448.7 thousand hectares with a contribution of 169.7 thousand tones to the annual oilseed production of the country Its average productivity is 378 kg/ ha. Major linseed

Growing states are Madhya Pradesh (M.P.), Uttar Pradesh (U.P.), Chhattisgarh, Bihar, Rajasthan, Orissa and Karnataka.[32]. Ethiopia is one of the top 5^{th} major producers of linseed in the world

After Canada, China, United States and India.

The principal linseed growing regions in Ethiopia are located at altitudes between 1800 and 2800 meter above sea level (mash), although it occasionally grows at altitudes as low as 1680 masl or as high as 3430 mash. Arsi, Bale, Chercher Mountains, Eastern Welega, Eastern

Gojam, Tigray, Southeast Wello, and Shoa are the major areas of production and South Gondar, Kefa, Gemogofa and Illubabor are small-scale production areas in Ethiopia.

Linseed is a multi-purpose crop. Its' seeds containing about 36-40% of oil, have long been used in human and animal diets and in industry as a source of oil and as a basic component or additive of various paints or polymers. Recently, there has been a growing interest in the

Probiotic properties of flax and in its beneficial effects on coronary heart disease, some kinds of Cancer and neurological and hormonal disorders

.

Figure 2.3Linseed crop

Figure 2.4Linseed

2.3.1 Technologies in Biodiesel Production

There are three basic chemical processes used to produce biodiesel from oils and fats industrially. These processes can either be batch or continuous and are the following:

- ✓ Base catalyzed transesterification of the oil with alcohol (methanol).
- ✓ Direct acid catalyzed esterification of the oil with methanol.
- ✓ Conversion of the oil to fatty acids (acid pretreatment) and then to alkyl esters with acid catalysis.

Of the pro-mentioned methods available for producing biodiesel, transesterification of natural oils and fats is currently the method of choice. The purpose of the process is to lower the viscosity of the oil or fat. Transesterification is basically a sequential reaction (Figure 2.1). Triglycerides are first reduced to diglycerides, which are subsequently reduced to monoglycerides, which are finally reduced to fatty acid esters. The order of the reaction changes with the reaction conditions. The main factors affecting transesterification are the molar ratio of glycerides to alcohol, catalysts, reaction temperature and time, and free fatty acid and water

content in oils and fats. Biodiesel as it is defined today is obtained by transesterifying triglycerides with methanol. Methanol is the preferable alcohol for obtaining biodiesel because it is the cheapest alcohol (Demirbas A., 2008).

2.3.2. Oil from linseed

Biodiesel from linseed oil was produced by reacting it with methanol in the presence of KOH. An experimental study was also carried out to examine the fuel properties, performance characteristics of different blends of used linseed biodiesel in comparison to diesel fuel. Performance characteristics like brake power, brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature of biodiesel blended fuelled C.I. engine were evaluated and compared with that by fuelling diesel while the engine running at no, part and full load condition. The objectives of this experimental study are to assess performance characteristics of a diesel engine when tested with selected fuels and compared with diesel as a reference fuel.

2.3.3. Biodiesel production processes

Filtered linseed oil is heated up to 110 degree Celsius to remove water content & avoid soap formation and cool down 55 degree Celsius. Methyl alcohol (with molar ratio of3:1, 6:1 & 4.5:1) and catalyst KOH (0.5%, 0.75% and 1% by weight of oil) mixed with oil and stirred until KOH dissolve in Methyl alcohol. All 3 materials stirred well by magnetic stirrer under temp range of 55-60 degree Celsius. After completion of reaction separation of FFA (free fatty acids) takes place. Separation of Methyl Ester and glycerol will take 2 to 3 hr duration. After separation Methyl Ester (Biodiesel) visible in the upper layer and FFA (glycerol) at the bottom.Bio-diesel is separated from beaker for removing impurities (catalyst and excess Methanol) by purification process. Excess methanol present in biodiesel has been removed by vaporization. To remove the catalyst, water at around 40 degree C is mixed with the Methyl ester and left for settling down. Water due to its higher specific gravity collected at bottom, Excess water is removed by heating the biodiesel.

2.3.4. Raw materials treatment

The raw materials, which can be vegetable oils, animal fats, or recycled greases, used in the production of biodiesel contain triglycerides, free fatty acids, water, and other contaminants in

various proportions. Some crude vegetable oils contain phospholipids that need to be removed in a degumming step.

Phospholipids can produce lecithin, a commercial emulsifier (Van Gerpen and Dvorak, 2002). Liu et al. compared the different degumming methods, such as membrane filtration, hydration, acid micelles degumming, supercritical extraction, etc. The characteristics of the raw oils should be investigated before choosing the suitable degumming method because different degumming methods have their advantages and disadvantages (Liu *et al.,* 2008). The oil can be separated through membrane filtration according to the average molecular weight or the particle size of phospholipids. Although degumming method can solve the problem, its process involves two steps with the use of an organic solvent. Therefore, this method has no superiority on cost because of its complicated processing (Carvalho*et al*., 2006; Souza, 2008).

In the hydration process, because of phospholipids hydrophilicity, hot water can be added into the oil with stirring. The phospholipids solubility will be significantly reduced, so it could be separated from the oil by natural settlement. The hydration method features a simple process, easy operation, and high yields refining, but non-hydra table phospholipids cannot be removed by this method, as reported by

Verleyen et al (Verleyen et al., 2002). For removing non-hydra table phospholipids (NHP), critic acid or phosphoric acid can be added into the oil which is heated to 70^0C, this is called the special micelles degumming method. Moreover, by refining with supercritical CO_2 extraction, it can effectively remove the free fatty acids and the per oxidation products that are in the crude oil. However, the high pressure required in this process will be the biggest challenge in its industrial application (Eisenmenger and Dun ford, 2008; Chen et al., 2007) The free fatty acids are removed in a refining step and excess free fatty acids can be removed as soaps in a later pretreatment step. In addition, deodorization is another important step in the raw material treatment (Demirbas and Kara, 2006). Next, in order to determine the percentage of FFA in the oils or fats, titration is performed. As described above, if the percentage of FFA is over 2.5 wt. %, pretreatment is necessary to reduce the content of FFA. This step also determines the amount of catalyst required in the neutralization step

2.3.5. Pre-treatment of acidic feed stocks

Many pretreatment methods have been proposed for reducing the high free fatty acid content of the oils, including steam distillation, extraction by alcohol (Turkay& Civelekoglu,1991), and esterification by acid catalysis (Zhang et al., 2008). However, steam distillation for reducing high free fatty acids requires a high temperature and has low efficiency. Because of the limited solubility of free fatty acids in alcohol, extraction by alcohol method needs a large amount of solvent and the process is complicated.

Compared with the two former methods, esterification by acid-catalysis makes the best use of the free fatty acids in the oil and transforms it into biodiesel. The catalysts can be homogeneous acid-catalysts or solid acid-catalysts. Compared with the former one, solid acid-catalysts offer some advantages for eliminating separation, corrosion, toxicity, and environmental problems, but the reaction rate is slower (Zhang et al., 2008; Serio et al.,2005). An alternative approach to reduce the FFA is to use iodine as a catalyst to convert free fatty acids into biodiesel. An obvious advantage of this approach is that the catalyst (iodine) can be recycled after the esterification reaction. Li et al. (2008) found through orthogonal tests, under the optimal conditions (i.e. iodine amount: 1.3 wt. % of oils; reaction temperature: 80^0C; ratio of methanol to oils: 1.75:1; reaction time: 3h) that the FFA content can be reduced to < 2%. Another new method of pretreatment is to add glycerol into the acidic feedstock and heat it to a high temperature of about 200^0C, normally with a catalyst such as zinc chloride. The glycerol will react with the FFA to form monoglycerides and diglycerides. Then the FFA level will become low and biodiesel can be produced using the traditional alkali-catalyzed transesterification method. The advantage of this approach is that no alcohol is needed during the pretreatment and the water formed from the reaction can be immediately vaporized and vented from the mixture. However, the drawbacks of this method are its high temperature requirement and relatively slow reaction rate (Van Gerpen, 2004).

2.3.6. Catalyst and alcohol

In general, there are three categories of catalysts used for biodiesel production: alkalis, acids, and enzymes. Enzyme catalysts have become more attractive recently since it can avoid soap formation and the purification process is simple to accomplish. However, they are less often used commercially because of the longer reaction times and higher cost. To reduce the cost, some

researchers developed new biocatalysts in recent years. An example is so called whole cell biocatalysts which are immobilized within biomass support particles. An advantage is that no purification is necessary for using these biocatalysts.

Compared with enzyme catalysts, the alkali and acid catalysts are more commonly used in biodiesel production. The alkali and acid catalysts include homogeneous and heterogeneous catalysts. Due to the low cost of raw materials, sodium hydroxide and potassium hydroxide are usually commercially used as alkali homogeneous catalysts. These materials are the most economic because the alkali-catalyzed transesterification process is carried out under a low temperature and pressure environment, and the conversion rate is high with no intermediate steps. However, the alkali homogeneous catalysts are highly hygroscopic and absorb water from air during storage. They also form water when dissolved in the alcohol reactant and affect the yield. Therefore, they should be properly handled. On the other hand, some heterogeneous catalysts are solid and it could be rapidly separated from the product by filtration, which reduces the washing requirement (Dennis *et al.,* 2010). In addition, solid heterogeneous catalysts can stimulatingly catalyze the transesterification and esterification reaction that can avoid the pre-esterification step, thus these catalysts are particularly useful for those feed stocks with high free fatty acid content. However, using a solid catalyst, the reaction proceeds at a slower rate because the reaction mixture constitutes a three-phase system, which, due to diffusion reasons, inhibits the reaction. The alcohol materials that can be used in the transesterification process include methanol, ethanol, propanol, butanol, and amyl alcohol. Among these alcohols, methanol and ethanol are used most frequently. Methanol is especially used because of its lower cost and its physical and chemical advantages. Ma and Hanna (1999) reported that methanol can react with triglycerides quickly and the alkali catalyst is easily dissolved in it. However, due to its low boiling point, there is a large explosion risk associated with methanol vapors which are colorless and odorless. Both methanol and meth oxide are extremely hazardous materials that should be handled carefully. It should be ensured that one is not exposed to these chemicals during biodiesel production (Qianet al., 2008).

2.3.7. Mixing and neutralization

The purpose of mixing methanol with the catalyst is to produce meth oxide which reacts with the base oils. Most of the catalysts (e.g. NaOH, KOH) are in solid form and do not readily dissolve

into methanol, it is best to start agitating the methanol in a mixer and add the catalyst slowly and carefully (ISTC, 2006). Once the catalyst completely dissolves in the methanol, the meth oxide is ready to be added to the oil. Once the meth oxide is added into the oil, a neutralization reaction will immediately start. Some alkali catalysts will react with rudimental acids during the pretreatment step or will react with the free fatty acids from the oil. Therefore, more catalyst needs to be added to complete the reaction.

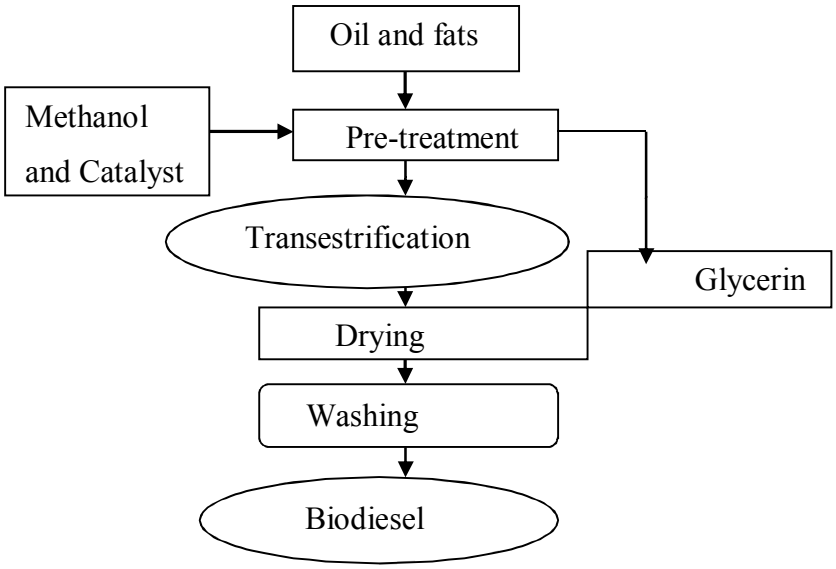


Figure2.5Block diagram of production of biodiesel procedure

2.3.8. Transesterification and separation

When the catalyst, alcohol, and oil are mixed and agitated in a reaction vessel, a transesterification reaction will start. A stirred reactor is usually used as the reaction vessel for continuous alkali-catalyzed biodiesel production. Recently, there is an increased interest in new technologies related to mass transfer enhancement. As previously mentioned, if the free fatty acid level or water level is too high, it may cause problems downstream with the saponification and the separation of the glycerol by-product. Therefore, the amount of water and free fatty acids in the feedstock oil should be monitored during the reaction. Once the transesterification reaction is completed, two major products exist: esters (biodiesel) and glycerol. The glycerol phase is much denser than the biodiesel phase and settles at the bottom of the reaction vessel, allowing it to be separated from the biodiesel phase. Phase separation can be observed within 10 min and can be completed within several hours of settling. The reaction mixture is allowed to settle in the

reaction vessel in order to allow the initial separation of biodiesel and glycerol, or the mixture is pumped into a settling vessel. In some cases, a centrifuge may be used to separate the two phases (Van Gerpen, 2004). Both the biodiesel and glycerol are contaminated with an unreacted catalyst, alcohol, and oil during the transesterification step.

Soap that may be generated during the process also contaminates the biodiesel and glycerol phase. Schumacher (2007) suggested that although the glycerol phase tends to contain a higher percentage of contaminants than the biodiesel, a significant amount of contaminants is also present in the biodiesel. Therefore, crude biodiesel needs to be purified before use.

2.3.9. Refining crude glycerol

Although biodiesel is the desired product from the reactions, the refining of glycerol is also important due to its numerous applications in different industrial products such as moisturizers, soaps, cosmetics, medicines, and other glycerol products. It is one of the few products that has a good reactivity on sump oil, and is extremely effective for washing shearing shed floor, so it can be used as a heavy duty detergent and degreaser. Whittington (2006) reported that glycerol can even be fermented to produce ethanol, which means more bio fuel can be produced. According to the statements of Van Gerpen*et al.* (2004), typically produced glycerol is about 50% glycerol or less in composition and mainly contains water, salts, unreacted alcohol, and unused catalyst (Dennis *et al*., 2010). The unused alkali catalyst is usually neutralized by an acid. In some cases, hydrochloric or sulphuric acids are added into the glycerol phase during the re-neutralization step and produce salts such as sodium chloride or potassium sulphate, the latter can be recovered for use as a fertilizer. Generally, water and alcohol are removed to produce 80–88% pure glycerol that can be sold as crude glycerol. In more sophisticated operations, the glycerol is distilled to 99% or higher purity and sold in different markets. After the re-neutralization step, the alcohol in the glycerol phase can be removed through a vacuum flash process or by other types of evaporators. Usually, the alcohol vapor is condensed back into liquid and reused in the process. However, the alcohol may contain water that should be removed in a distillation column before the alcohol is returned to the process. The alcohol recovery step is more difficult when the alcohol that is used, such as ethanol or is propanol, forms an zoetrope with the water. Gerpen (2005) proposed the use of a molecular sieve to remove the water generated.

2.3.10. Purification of crude biodiesel

After separation from the glycerol phase, crude biodiesel is mainly contaminated with residual catalyst, water, unreacted alcohol, free glycerol, and soaps that were generated during the trans-esterification reaction. Normally, crude biodiesel enters a neutralization step and then passes through an alcohol stripper before the washing step. In some cases, acid is added to crude biodiesel to neutralize any remaining catalyst and to split any soap. Soaps react with the acid to form water soluble salts and free fatty acids. Gerpen (2005) stated that neutralization before the washing step reduces the materials required for the washing step and minimizes the potential for emulsions being formed during the washing step. Unreacted alcohol should be removed with distillation equipment before the washing step to prevent excess alcohol from entering the wastewater effluent. The primary purpose of this step is to wash out the remnants of the catalyst, soaps, salts, residual alcohol, and free glycerol from the crude biodiesel. Generally, three main approaches are adopted for purifying biodiesel: water washing, dry washing, and membrane extraction (Dennis et al., 2010).

2.3.11. Water washing

Since both glycerol and alcohol are highly soluble in water, water washing is very effective for removing both contaminants. It also can remove any residual sodium salts and soaps. The primary material for water washing is distilled warm water or softened water (slightly acidic) (Chen et al., 2007; Demirbas & Kara, 2006). Warm water prevents the precipitation of saturated fatty acid esters and retards the formation of emulsions with the use of a gentle washing action. Softened water (slightly acidic) eliminates calcium and magnesium contamination and neutralizes any remaining alkali catalysts.

After washing several times, the water phase becomes clear, meaning that the contaminants have been completely removed. Then, the biodiesel and water phases are separated by a separation funnel or centrifuge. Moreover, because of the immiscibility of water and biodiesel, molecular sieves and silica gels, etc., can also be used to remove water from the biodiesel. The remaining water can be removed from the biodiesel by passing the product over heated Na_2SO_4 (25 wt. % of the amount of the ester product) overnight and then be removed by filtration.

However, there are many disadvantages to this method, including an increased cost and production time, polluting liquid effluent, product loss, etc. Moreover, emulsions can form when washing the biodiesel made from waste cooking oils or acidic feed stocks because of the soap formation (Dennis et al., 2010).

2.3.12. Dry washing

Dennis *et al.* (2010) used dry washing by replacing the water with an ion exchange resin or a magnesium silicate powder in order to remove impurities. These two dry washing methods can bring the free glycerol level down and is reasonably effective for removing soaps. Both the ion exchange process and the magnesol process have the advantage of being waterless and thus eliminate many of the problems outlined above. Although the magnesol process has a better effect on the removal of methanol than the ion resins, none of the products from this process fulfill the limits specified in the EN Standard.

2.3.13. Characterization of biodiesel fuels

For commercial fuel, the finished biodiesel must be analyzed using sophisticated analytical equipment to ensure it meets inter-national standards. A few specifications have been set but the ASTM D6751 and EN14214 standards are the most commonly used standards. Some properties in the standard, such as the cetane number or density, can reflect the properties of the chemical compounds that make up the biodiesel, and other properties provide an indication of the quality of the production process.

Generally, biodiesel standards identify the parameters that pure biodiesel must meet before being used as a pure fuel or being blended with distillate fuels (Dennis *et al*., 2010). To ensure safe operation in diesel engines, the most important aspects of the biodiesel product are the completion of the reaction, the removal of the free glycerol, residual catalyst and alcohol, and the absence of free fatty acids (Zhen *get al.,* 2008). As mentioned before, if the transesterification reaction is not complete then triglycerides, diglycerides, or monoglycerides may be left in the final product. Chemically, each of these compounds contains a glycerol molecule. Fuel with excessive free glycerol may plug the fuel filter sand cause combustion problems in the diesel engine. Therefore, the ASTM standard requires the total glycerol to be <0.24% of the final biodiesel product.

On the other hand, since residual methanol, even as little as 1%, can lower the flashpoint of the final biodiesel product from 170^0C to $<40^0$C, the EN 14214 standard limits the amount of alcohol to a very low level (Van Gerpen*et al.*, 2004). Finally, although a specific value for the residual catalyst is not included in the ASTM standard, it is limited by the specification on levels of sulfated ash, which may lead to engine deposits and high abrasive wear levels. Because the European specification for sulfur content is much tighter than the US requirement, Ali et al. (1995) reported that a number of producers in Europe are resorting to the use of vacuum distillation for the removal of sulfur compounds from the final biodiesel product. In addition, some vegetable oils, yellow greases, and brown greases leave an objectionable color in the biodiesel. Although there is no color specification in the ASTM standard, in some cases, an activated carbon bed, which is an effective method for the removal of excessive color, is used to produce a colorless biodiesel (National Biodiesel Board, 2007).

2.4 Storage of Biodiesel Product

Biodiesel is safe to store and the properties of biodiesel should conform to respective standards after it has been stored for a longtime. There are several key factors that need to be considered for the storage of biodiesel, including exposure temperature, oxidative stability, fuel solvency, and material compatibility (Leung et al., 2006). Lee et al. (1995) stated that the temperature of stored biodiesel should be controlled so as to avoid the formation of crystals which can plug fuel lines and fuel filters. For this reason, the storage temperature of most pure biodiesel is generally kept between 7 and 10^0C. Even in extremely cold climates, underground storage of pure biodiesel usually provides the storage temperature necessary for preventing crystal formation (Van Gerpen et al., 2004).

Bondioli et al. (1995) noted that the stability of biodiesel is an important property when it is to be stored for a prolonged period. Poor stability can lead to an increased acid value and fuel viscosity and to the formation of gums and sediments. Therefore, if the duration of storing biodiesel or biodiesel blends is more than 6 months, it should be treated with an antioxidant additive (Van Gerpen et al., 2004). Moreover, because water contamination will lead to biological growth in the fuel, it should be minimized in the stored fuel by using biocides. Biodiesel storage tanks made of aluminum, steel, Teflon, and fluorinated polyethylene or polypropylene should be

selected. The tanks should minimize the possibility of water contamination and should be cleaned prior to use for biodiesel storage (Mittelbach and Gangl, 2001)[35].

2.5. Factors Affecting Biodiesel Production

The process of transesterification brings about drastic change in viscosity of the vegetable oil. The high viscosity component, glycerol, is removed and hence the product has low viscosity like the fossil fuels. The biodiesel produced is totally miscible with mineral diesel in any proportion. Flash point of the biodiesel is lowered after transesterification and the cetane number is improved. The yield of biodiesel in the process of transesterification is affected by several process parameters which include; presence of moisture and free fatty acids(FFA), reaction time, reaction temperature, catalyst and molar ratio of alcohol and oil [35,36].

2.5.1. Reaction Temperature

Reaction temperature is the important factor that will affect the yield of biodiesel. For example, higher reaction temperature increases the reaction rate and shortened the reaction time due to the reduction in viscosity of oils. However, the increase in reaction temperature beyond the optimal level leads to decrease of biodiesel yield, because higher reaction temperature accelerates the saponification of triglycerides ([37] and causes methanol to vaporize resulting in decreased yield [38]. Usually the trans-esterification reaction temperature should be below the boiling point of alcohol in order to prevent the alcohol evaporation. The range of optimal reaction temperature may vary from 50°c to 60°c depends upon the oils or fats used [37]. Therefore, the reaction temperature near the boiling point of the alcohol is recommended for faster conversion by various literatures. At room temperature, there is up to 78% conversion after 60 minutes, and this indicated that the methyl esterification of the FFAs could be carried out appreciably at room temperature but might require a longer reaction time. In butyl esterification, however, temperature had stronger influence. Temperature increases the energy of the reacting molecules and also improves the miscibility of the alcoholic polar media into a non-polar oily phase, resulting in much faster reactions [39].

2.5.2. Reaction time

The increase in fatty acid esters conversion observed when there is an increase in reaction time. The reaction is slow at the beginning due to mixing and dispersion of alcohol and oil. After that

the reaction proceeds very fast. However the maximum ester conversion was achieved within < 90 min. Further increase in reaction time does not increase the yield product i.e. biodiesel/mono alkyl ester. Besides, longer reaction time leads to the reduction of end product (biodiesel) due to the reversible reaction of trans esterification resulting in loss of esters as well as soap formation [37] and 40].

2.5.3. Molar ratio

One of the most important parameters affecting the yield of biodiesel is the molar ratio of alcohol to triglyceride. Stoichiometrically ally 3 moles of alcohol and1 mole of triglyceride are required for trans-esterification to yield 3 moles of fatty acid methyl/ethyl esters and 1 mole of glycerol is used. In order to shift the reaction to the right, it is necessary to either use excess alcohol or remove one of the products from the reaction mixture. The second option is usually preferred for the reaction to proceed to completion. The reaction rate is found to be highest when 100% excess methanol is used [41 and37].Methanol, ethanol, propanol, butanol and amyl alcohol can be used in the trans-esterification reaction, amongst these alcohols methanol is applied more frequently as its cost is low and it is physically and chemically advantageous (polar and shortest chain alcohol) over the other alcohols. In contrast, ethanol is also preferred alcohol for using in the trans-esterification process compared to methanol since it is derived from agricultural products and is renewable and biologically less offensive in the environment. The effect of volumetric ratio of methanol and ethanol to oil was studied. Results exhibit that highest biodiesel yield is nearly 99.5% at 1:6 oil/methanol. In comparison, biodiesel yield using methanol continuously increases with the raise of methanol molar ratio [42].

2.5.4. Type and Amount of Catalyst

Biodiesel formation is also affected by the concentration of catalyst. Most commonly used catalyst for biodiesel production is sodium hydroxide (NaOH) or Potassium hydroxide (KOH). The type and amount of catalyst required in the trans-esterification process usually depend on the quality of the feedstock and method applied for the trans-esterification process.

For a purified feedstock, any type of catalyst could be used for the transesterification process. However, for feedstock with high moisture and free fatty acids contents, homogenous

transesterification process is unsuitable due to high possibility of saponification process instead of transesterification process to occur.

The yield of fatty acid alkyl esters generally increases with increasing amount of catalyst. This is due to availability of more active sites by additions of larger amount of catalyst in the transesterification process. However, on economic perspective, larger amount of catalyst may not be profitable due to cost of the catalyst itself. Therefore, similar to the ratio of oil to alcohol, optimization process is necessary to determine the optimum amount of catalyst required in the transesterification process [43].

2.5.5. Mixing Intensity

Oils and alcohols are not totally miscible, thus reaction can only occur in the interfacial region between the liquids and trans-esterification reaction is a moderately slow process. So, Mixing is very important in the trans-esterification process, adequate mixing between these two types of feedstock is necessary to promote contact between these two feed stocks, therefore enhance the trans-esterification reactions to occur [44]. Most literatures indicate that during the trans-esterification reaction, the reactants initially form a two-phase liquid system. The mixing effect has been found to play a significant role in the slow rate of the reaction. As phase separation ceases, mixing becomes insignificant. The effect of mixing on the kinetics of the trans-esterification process forms the basis for process scale-up and design [45].The intensity of the mixing could be varied depending on its necessity in the trans-esterification process. In general, the mixing intensity must be increase viscosity are used as the feedstock, intensive mechanical mixing is required to overcome the negative effect of viscosity to the mass transfer between oil, alcohol and catalyst [46].

2.5.6. Free fatty acid and water content

The FFA and moisture contents have significant effects on the trans-esterification of glycerides with alcohol using catalyst. The high FFA content (>1% w/w) will happen soap formation and the separation of products will be exceedingly difficult, and as a result, it has low yield of biodiesel product. In addition formation of gels and foams hinders the separation of glycerol from biodiesel. For instance, Water content in waste cooking oil will accelerate the hydrolysis reaction and simultaneously reduce the amount of ester formation.

To overcome this problem, supercritical methanol method was proposed. It may be noted that water has less influence in supercritical methanol method. Therefore, water content should not always exceed0.5% to obtain 90% yield of biodiesel and it is more critical for an acid-catalyzed reaction than base catalyzed reaction. Stated the moisture levels of the collected waste chicken fats vary widely, being as high as 18%.Therefore, it is not possible to convert these oils to biodiesel by using a single process. One drawback of biodiesel is that there is an inverse relationship between biodiesel's oxidative stability and its cold flow properties. Saturated compounds are less prone to oxidation than unsaturated compounds but they raise the cloud point of the fuel. The reaction of FFAs with alcohol produces ester, but also water that inhibits the of the transesterification glycerides. This is due to the effect of the water produced when the FFAs react with the alcohol to form esters. The coincidence of the lines indicates that water formation is the primary mechanism limiting the completion of the acid catalyzed esterification reaction with FFAs.

2.5.7. Purity of reactants

Impurities present in the vegetable oil also affect ester conversion levels significantly. The vegetable oil (refined or crude oil) is filtered before the trans-esterification reaction. The oil settled at the bottom of the tank during storage would give lower yield because of deposition of impurities such as wax.

2.6. Production of biodiesel from linseed oil and oil yield

Flax (linseed) is a plant of temperate climates, with blue flowers. Linen is made with the threads from the stem of the plant and the oil from the seeds is called linseed oil, used in paint manufacture. Moreover, the cake left over, following oil extraction, is used as a live stock feed.

The plant adapts well to a wide range of temperature and humidity; however, high temperatures and plentiful rain do not favor high yields of seed and fiber. Flax seeds contain between 30 and 48% of oil, and protein content is between20 and 30%. It is important to remark that linseed oil is rich in polyunsaturated fatty acids, linolenic acid being from 40 to 68% of the total. Biodiesel from linseed oil through transesterification process and evaluated on varying the various parameters such as reaction time, KOH concentration and molar ratio. Filtered linseed oil is heated up to 110 degree Celsius to remove water content & avoid soap\ formation and cool down

55 degree Celsius. Methyl alcohol (with molar ratio of3:1, 6:1 & 4.5:1) and catalyst KOH (0.5%, 0.75% and 1% by weight of oil) mixed with oil and stirred until KOH dissolve in Methyl alcohol. All 3 materials stirred well by magnetic stirrer under temp range of 55-60 degree Celsius. After completion of reaction separation of FFA (free fatty acids) takes place. Separation of Methyl Ester and glycerol will take 2 to 3 hr duration. After separation Methyl Ester (Biodiesel) visible in the upper layer and FFA(glycerol) at the bottom. Bio-diesel is separated from beaker for removing impurities (catalyst and excess Methanol) by purification process. Excess methanol present in biodiesel has been removed by vaporization. To remove the catalyst, water at around 40 degree C is mixed with the Methyl ester and left for settling down. Water due to its higher specific gravity collected at bottom, Excess water is removed by heating the biodiesel.

2.7. Ethanol

Ethanol production for use as a gasoline-blending component began in the U.S. in the late 1970swhen it was used as a product extender (gasohol) during the OPEC oil restriction. Fuel grade ethanol production, primarily corn-based, has grown from approximately 175 million gallons in1980 to over 1.63 billion gallons in 2000. There are currently 62 ethanol production facilities in the United States, located in twenty different states, although the majority of production (roughlym 90%) occurs in the Midwest and north-central states of Indiana, Illinois, Iowa, Minnesota, and Nebraska. Total U.S. ethanol nameplate production capacity is over two billion gallons per year(as of late 2000), and 2001 annual production is expected to be near 2 billion gallons.

The majority of ethanol is produced from corn, and the National Corn Growers Association expects production capacity for corn-based ethanol to double in the next five years (Watkins, 2001).

Research continues on the development of efficient, cost-effective processes for producing ethanol from other feedstocks such as waste from agricultural crops, food and beverage processing, wood and paper processing, and municipal refuse. The goal of the DOE National Bio ethanol Program (Ferrel, 2000) is to establish an economically viable and environmentally sound supply of bio ethanol with the potential to produce 8 billion gallons per year by 2025 and as

much as 50 billion gallons by 2050. The DOE National Bio ethanol Program focuses on the production of ethanol from cellulosic feedstock's found in all plant matter. These "bio polymers "are like starch (used in the ethanol production process from corn), but with three important differences:

1) Hemicelluloses and cellulose represent the most abundant form of stored carbon in nature;
2) The chains of sugars are more difficult to hydrolyze; and
3) Hemicelluloses contain unique sugars that are not as readily fermented. These differences represent the key technical challenges the Program faces. (Ferrell, 2000)

The Program supports a portfolio of activities that is balanced across the variety of technology development. DOE is helping to initiate open up production facilities using new ethanol production processes. In partnership with biotechnology companies, they are developing better enzymes that will replace sulfuric acid hydrolysis with biological hydrolysis resulting in higher yields and lower production costs. By reducing the cost and technical risk, DOE intends to achieve the Program production metric of 8 billion gallons per year of ethanol in the marketplace by 2025. Thus DOE anticipates ethanol for fuel use to be widely available for the foreseeable future.

Alcohols are defined by the presence of a hydroxyl group (–OH) attached to one of the carbon atoms. Ethanol, in particular, (or ethyl alcohol) is a biomass based renewable fuel (bio-ethanol), which can be produced, relatively easily and with low cost, by alcoholic fermentation of sugar from vegetable materials, such as corn, sugar cane, sugar beets, barley, and from (non-food) agricultural residues such as straw, feedstock and waste woods. Ethanol is isomeric with di methyl ether (DME) and both ethanol and DME can be expressed by the chemical formula C_2H_6O. Although they may have the same physical formula, the thermodynamic behavior of ethanol differs significantly from that of DME on account of its stronger molecular association via hydrogen bonds.

Because of its high octane number, ethanol is considered primarily a good spark-ignition engine fuel. Nonetheless, it has been considered also a suitable fuel for compression ignition engines, mainly in the form of blends with diesel fuel. For the latter case, cetane improvers and/or glow plugs were implemented combined with an increase in the engine compression ratio to facilitate

ignition, particularly during cold starting. Another successful method for using alcohols in diesel engines is fumigation

2.7.1. Ethanol Markets

Currently, the largest market for ethanol is transportation fuel for passenger vehicles. Ethanol can be used in passenger vehicles, in any combination of blends, up to 10% without any vehicle modifications. This includes E-10, commonly referred to as "gasohol", oxygenated fuel, and reformulated gasoline (RFG). Higher blends, such as E-85, can only be used in modified vehicles. E-85 flexible fueled vehicles are manufactured by all three major automobile manufacturers, and are modified to run on ethanol blends up to 85%. There are also additional niche markets for ethanol-blended fuels, such as snowmobiles, airplanes, boats, and lawnmowers.

2.7.2. Ethanol Resources in Ethiopia

Ethiopia is viewed as one of the most suitable nations in Africa for tapping renewable sources of energy because of its location. This is the case not only for its own economy, but also for export to economies in the region, such as Kenya, Djibouti and Sudan. The country has also been looking at enhancing its energy capacity, especially over the past two ten years (Gebreegziabher and Mekonnen 2011). The government's recently issued bio fuel strategy to encourage domestic bio fuels production, with an objective of reducing the dependence on high-cost fossil oil, is also a manifestation of this endeavor (Mo ME 2007). Ethiopia is a country with a total land mass of 1.2 million km2 and is said to have an estimated potential area of about 25 million hectares of land suitable for production of biodiesel feedstock (Gebremeskel and Tesfaye 2008). Given rising world prices of fossil oil, the bio fuels industry has developed a very significant national presence. Accordingly, there are bio fuels investment activities in different regions of Ethiopia with a focus on bio ethanol and biodiesel production. Besides, Ethiopia get on a 5% blend of bio ethanol in transport fuel in 2008, which was doubled to 10% a few years later. Official reports also indicate that, by blending more than 38.2 million liters of bio ethanol with gasoline, the country has been able to save 30.9 million US dollars on oil imports since 2008 (Biofuel digest 2013). Although the recently launched Climate flexible Green Economy (CRGE) strategy of Ethiopia visualize 5% biodiesel blending in transport fuel by 2030 (FDRE 2011), biodiesel blending in transport fuel has not yet started in Ethiopia. As part of the planned large-scale

expansion in the sugar industry that is predetermined in Ethiopia's national Growth and Transformation Plan (GTP), the country also aims to produce 181,604 cubic meters of bio ethanol from sugar byproducts (from molasses) toward the end of the GTP period 2010/11-2014/15 (Mo FED 2010). In addition, constructing bio ethanol plants in conjunction with existing and upcoming sugar factories is underway.

However, the opportunities created and challenges posed by increased production of bio fuels have been a subject of considerable policy debate (Searchinger et al. 2008; Azar 2011) and the debate is still on-going. Though many countries engage in bio fuels production to diversify energy sources, reduce GHG emissions and/or reduce dependency on imported fossil fuels, the profitability of bio fuels production has been less explored. Moreover, volatility of world fuel prices leads to variability of prices of both bio fuel and feedstock's. Uncertainties in prices in turn influence viability of bio fuels investments.

Therefore, it is natural to ask "will it be economically feasible to produce bio fuels?" This paper is coming out of broader research projects on "impacts and profitability of bio fuels in Ethiopia" that looked into the various dimensions of the bio fuels debate. Gebreegziabher et al. (2013) examine the distributive (interests) effects and food security implications of bio fuels investment in Ethiopia. Ferede et al.(2013) look at bio fuels, economic growth, and the external sector in Ethiopia.

The potential for producing fuel alcohol from molasses and other raw materials, including trees such as eucalyptus, is quite large in Ethiopia. In fact, if considered seriously, production of bio ethanol from biomass is considered to have a double dividend, i.e., solving the fuel problem and fighting deforestation (Bayissa 2002). The country is also said to have high potential for biodiesel production (Gebremeskel and Tesfaye 2008). The current bio fuel development strategy in the country emphasizes the production of bio ethanol from sugar beet, sugar cane, sweet sorghum and others, and biodiesel from jatropha, castor bean plants, and palm (Mo ME 2007). Previously, there was only one bio fuel factory in Ethiopia, a power alcohol plant that has been producing bio ethanol as a byproduct at Fincha Sugar Factory. Fincha has a distillery (an ethanol plant) appropriate to its sugar mill with a capacity of 12 million liters/year. The plant was commissioned in 1998 and produces ethanol from sugarcane molasses, a byproduct of the sugar mill; it had a stock of about four million liters of bio-ethanol at the end of December 2001

(Bayissa 2002). However, although the government had issued a directive allowing Fincha to produce and sell fuel alcohol to oil companies, who would in turn blend it with gasoline and distribute it to motorists, it could not sell its fuel alcohol on the market at that time. The major reasons for the refusal of the oil companies appeared to be the need for rehabilitating the existing old fuel stations and lack of interest in investing in a fuel sales operation that gives them little profit. This was also viewed as a lack of understanding and absence of commitment to alleviate one of the major problems of the country.

However, the interest in bio fuels development has been recharged with the recent hike in oil prices. Several local and international private and public bio-fuels companies (developers) have registered in the country since 2006. For example, by 2010 there were more than 82 registered bio-fuel investors (see Table A1 in the appendices), most of which were registered for the cultivation of energy crops for biodiesel production. In the case of bio-ethanol, however, there are only a few developers in the country, most of which are publicly owned sugar factories that intend to produce bio-ethanol as a byproduct of sugar production. Reports also indicate that about 1.5 to 2 million hectares of land have already been offered for bio-fuels investment (ABN 2007; Lashitew 2008; Lakew and Shiferaw 2008; Beyene 2011).

2.7.3. Current Status of Ethanol and Sugar Production in Ethiopia

The worldwide recent awareness for the use of ethanol to replace petroleum and generation of power along with sugar mill plants should have led to setting up of number of ethanol plants and co-generations. There is only one sugar mill producing ethanol & few distilleries participating in downstream chemicals from alcohol in the country at present due to poor economy of scales.

Among molasses derived products ethanol takes the largest part, but its utilization must attract the attention of the government policy makers in order to utilize as a bio ethanol. Bio ethanol or bio fuel is ethanol-based products that can process into liquid fuels for either transport or heating purposes. With the coming into being of the sugar sector expansion and modernization in the country, implementation of the different domestic measures for bio ethanol fuels utilization has to take place. At present there was about 8000 cubic meter annual production of ethanol, but there are projects towards increasing the product to over 142000 cubic meter (ESDA, 2005).

2.7.4. Bio-ethanol

The viability analysis of bio ethanol production is carried out based on a detailed breakdown of four years (2007 to 2010) of bio-ethanol production cost data obtained from Fincha Sugar Factory which is item and cost (ETB) relation. Note that the discussion of results is based on a four-year average. As feedstock, supplies and other costs constitute important cost components in the context of Ethiopia. The results also suggest that bio-ethanol can be produced in Ethiopia with the cost of ETB 3.19/gallon or ETB 0.84/liter at the factory gate. Moreover, the unit sales price of molasses bio-ethanol is analyzed based on a four year average .The results suggest that the unit sales price of molasses bio-ethanol at the factory gate in Ethiopia is ETB 3.23/gallon. Considering an exchange rate of ETB 13.5/US$ during August 2010, i.e., during the survey period, this is equivalent to a unit production cost of US$ 0.24/gallon and sales price of US$ 0.29/gallon or US$ 0.08/liter. Production costs, as well as sale prices at the factory gate for the years 2011and 2012, also obtained from the Fincha and Metehara sugar factories, are used to augment our analysis. The unit production costs at the factory ranged between ETB 2.73 and ETB4.70 per liter. The unit sale prices also ranged between ETB 3.00 and ETB 8.90 per liter. The data also suggest that the sales prices sufficiently cover production costs.

It would be of interest to provide an international perspective in order to visualize the viability and international competitiveness of Ethiopia's engagement in bio-ethanol production. The world ethanol price increased by 32% to $2.18 per gallon in 2010, after declining by 5.3% in 2009, partly due to a decline in ethanol exports from Brazil. Then, ethanol prices dropped in 2011. Though regional market conditions varied, world ethanol prices declined early in 2012 (OECD 2013). In general, movement in ethanol price is largely driven by what is happening in Brazil and the US, but also by movements in world oil price. For example, in the United States, with the extent of the drought becoming apparent, ethanol prices began to rebound in late 2012, driving up feedstock prices. In Brazil, improved supplies due to an improved sugar cane crop in the second half of 2012 pulled down domestic ethanol prices. As a net effect of all the various underlying factors, the world price of ethanol is expected to increase by 8% in real terms over the next decade between 2012 and 2022, slightly more than the 7% increase in oil prices expected during this period, before starting to increase over the first part of the projection period

Therefore, if ethanol price is projected to vary, say, between $1.5 and $2.5 per gallon in the next decade (FAPRI 2008; 2011), then, with the unit production cost equivalent to US$0.24/gallon, one can visualize that bio-ethanol production (from molasses) in Ethiopia is indeed viable and competitive internationally. Over the past few years, ethanol markets have been strongly influenced by the level of crude oil prices. Therefore, uncertainties in the fossil energy sector are directly translated into uncertainties in the ethanol and agricultural sectors. This is also due to the fact that ethanol production is expected to represent a sizeable part of the demand for agricultural feedstock (OECD/FAO 2013). Moreover, the sector is also vulnerable to perturbations in agricultural production caused by unfavorable climatic or weather conditions. It could be envisaged that all these uncertainties will have a bearing on bio-ethanol production of the count

2.7.5. Ethanol.-Diesel Blend Production

As noted, blending of ethanol and diesel occurs at the finished product terminal. Each is stored in its respective tank until drawn from inventory. The terminal must have a tank(s), of sufficient size to meet projected e-diesel demand. Blending systems must be installed (or existing blending systems modified) to accommodate ethanol-diesel blending. Additionally, piping modifications and modifications to the loading rack may, in some cases, be necessary. The estimated cost of installing a 25,000 barrel tank is $450,000 while costs for blending systems and modifications to receive ethanol at the terminal could push the cost to a total of $1.0 million. However if one assumes 24 inventory turns per year, this equates to a cost of only $0.007 per gallon of ethanol (29.4 cents per barrel) after amortizing the initial capital investment (Reynolds, 2000). Once blended at the terminal, the ethanol-containing blend is transported via truck to the retail outlet or fleet fueling facility. Facilities already producing ethanol-gasoline blends may not require additional ethanol storage but may require new storage capacity for e-diesel and for the emulsifier additive package that is also required (see below). E-diesel can be prepared by splash blending the components so no special blending equipment is required. However, as noted below, the flashpoint of e-diesel is much lower than that of conventional diesel so that in storage and transportation e-diesel must be handled like gasoline.

3. MATERIALS AND METHODS

3.1. Materials and Methods for Linseed Extraction

Materials: Linseed was collected from local market. It oil contains the oil content of 30.2%, on dry basis

3.1.1. Extraction process

The linseeds were cleaned manually to remove all foreign materials, such as dust, hand stone, dirt and broken and immature seeds.

3.1.2. Processes for obtaining vegetable oils (Linseed Oil extraction)

Commercially, there are three methods used for the production of vegetable oils: batch hydraulic pressing, continuous mechanical pressing and solvent extraction. Each of these technologies will be detailed below. The first step of the process, common to all technologies, is the preparation of raw material. The main unit operations used are scaling, cleaning, de hulling (or decorticating), cracking, drying, conditioning (or cooking), and flaking (Anderson, 2005). Although cooking operation is not included in the flowchart, it is a very important step in the processing of oilseeds. The flowchart below may be altered depending on raw material to be processed.

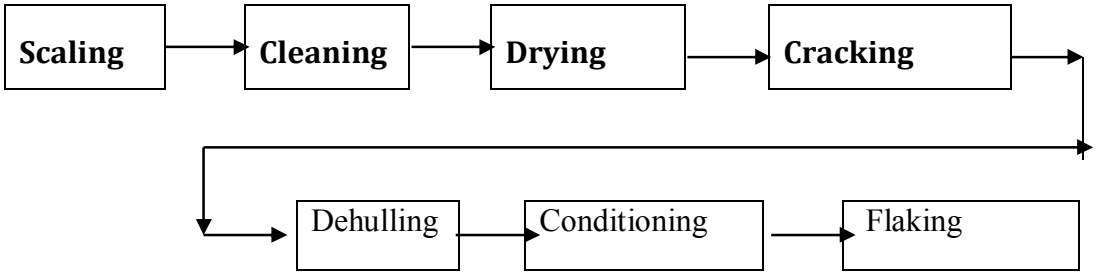


Figure 3.1Unit operations for raw materials preparation (adapted from Anderson, 2005)

Initially the oilseeds are weighed and sent to the cleaning step. A good quality oilseed has around 2% of impurities when it comes from the field. These foreign materials are removed when the oilseeds reach the storage unit and also before starting the extraction of oil. Due to the high oil content in its composition, oilseeds must have a low moisture content in order to prevent deterioration during storage and also to ensure that downstream unit operations are efficient.

This operation is conducted in a dryer (Kemper, 2005). The main goal of size reduction operation is to increase surface area to facilitate oil removal from the seed inside. This operation

must be conducted at proper moisture content. If the moisture level is too low, the seeds are "conditioned" with water or steam to raise the moisture to about 11%. A solvent extraction operation is going to have a higher yield if the flakes are about 0.203 to 0.254 mm. Thinner flakes tend to disintegrate during the solvent extraction process and reduce the miscella percolation rate (Wakelyn & Wan, 2006). Cracking mill is the equipment used to crack oilseeds. This equipment consists of two sets of cylindrical corrugated rolls in series, operating at differential speeds to assist in breaking the oleaginous materials apart (Kemper, 2005).

Another unit operation is Dehulling because some oilseeds present outer seed coat known as hull, rich in fiber and poor in oil and protein. The removal of these hulls will produce a better cake with high protein content by weight (Kemper, 2005). Another problem observed with hulled seeds is that the hull will reduce the total yield of oil by absorbing and retaining oil in the cake (Wakelyn & Wan, 2006). Dehulling process removes the lighter hull fraction by aspiration and also the fines, separated from the hulls through various means of hull agitation and screening. A Dehulling process can be considered effective if the levels of residual fiber content (from hulls) and residual oil content in the meal fraction were low (Kemper, 2005). Solvent extraction demands a flaking operation that distorts the cellular structure of the s material cells. and facilitates the percolation of the solvent in the oleaginous

Cooking is performed prior to extraction and has the following purposes:

(1) Break down cell walls to allow the oil to escape;

(2) Reduce oil viscosity;

(3) Control moisture content (to about 7% for expanding operation);

(4) Coagulate protein;

(5) Inactivate enzymes and kill microorganisms; and

(6) Fix certain phosphatides in the cake, which helps to minimize subsequent refining losses. Cooking temperatures are around 87.8°C during 120 min. An excess in the cooking time will result in a meal with lower nutritional value and can darken both the oil and meal (Wakelyn & Wan, 2006).

3.1.1.1. Batch hydraulic pressing

In the late nineteenth century, oilseeds were processed in manual presses, where layers of grains were placed into the equipment, separated by filter cloths and filter press plates and force was

applied via a hydraulic cylinder. When the oil has stopped flowing, the workers opened the machine, removed the mass of crushed grain and put more fresh material. At the beginning of the twentieth century the vegetable oil industry worked basically with the hydraulic presses but even making use of a hydraulic cylinder, work with this type of equipment was considered labor intensive.

In 2008 an article was published which focused on determination and modeling of yield and pressing rates for the hydraulic press type (Willems et al., 2008). The authors evaluated the influence of pressure profile, temperature, cover thickness and moisture content on the oil yields and rate of pressing for a variety of seeds (sesame, linseed, palm kernel, jatropha and rapeseed). The results showed that when the pressure is increased using a temperature of 100^{o}C and using the optimum moisture content (close to 2% dry basis), the oil yield increases for all tested oilseeds. The oil yield obtained for the dehulled seeds were considerably higher than that obtained for the hulled seeds. This can be explained by the absorption of oil by fibers present in the hulls. As a final conclusion, the authors stated that when using a press capable of applying a higher pressure (> 45 MPa), the oil yield is increased by 15% (oil / oil) compared with conventional presses.

3.1.1.2. Continuous mechanical pressing (screw press)

Among the physical processes for the extraction of vegetable oils, the continuous mechanical pressing emerges as the best technology to serve small farmers. That´s because this type of equipment associates both small scale and low cost when compared to the other methods mentioned. Another important advantage is the possibility of using cake resulting from the pressing as fertilizer or animal feed, since it is free of toxic solvents.

3.1.1.3 Solvent extraction

Extraction with solvents is the most effective method for the recovery of oil (almost 98%), especially with materials with low oil content, like soybeans. This method is not indicated to oilseeds with high oil content, like peanut and sunflower, requiring a prior step of pressing of the seeds and then the cake produced is extracted with a solvent. When performed at low temperature, the solvent extraction has another advantage over screw-pressing: better quality of

oil produced. This is because during expelling a sudden heating of the oil can occur, changing some parameters of its quality (Williams, 2005).

One of the disadvantages of the extraction is that the solvent extracts some non triglycerides, which does not occur in the expelling (Williams, 2005).Another serious problem is the presence of volatile organic impurities in the final product, which can compromise the quality and go against the new profile of consumers who are seeking for natural products aiming to have a healthier diet (Michulec & Wardenki, 2005).

3.2. Project Design

The oil was extracted in Addis Modjo edible Oil complex in Modjo town (for producing crude oil from linseed seed), by mechanical pressing. Transesterification and blending process was done in Chemistry department and Chemical engineering department of ASTU. Performance test was conducted in automotive work shop of ASTU. In over the entire project includes the following activities.

Seed preparation

- ✓ Production of oil from linseed by using mechanical pressing.
- ✓ Production of biodiesel using transesterification process.
- ✓ Washing biodiesel by using mist spray type
- ✓ Heat the washed biodiesel
- ✓ Preparing diesel-biodiesel and ethanol blends.
- ✓ Characterization of diesel-biodiesel and ethanol properties.
- ✓ Conducting performance test.
- ✓ Comparing the performance of pure diesel and diesel-biodiesel and ethanol blends

3.3. Materials

The following materials are used for conducting the experiment.

Table 3.1Materials used in transterification process

S.No	List of Materials
1	Linseed crude oil
3	Methanol
4	KOH
5	Distilled water

Table 3.2Materials used in transterification process

S. No	List of Equipments
1	Magnetic stirrer with hot plate
2	Decanter (separator funnel)
3	Digital balance
4	Glassware (Flasks)
5	Thermometer
6	Spray gun
7	Engine dynamometer
8	Four stroke four cylinder diesel Engine

Table 3.3 Vehicle specification

1	Engine model	Toyota 3L- 4122571
2	Stroke	4 stroke
3	Number of cylinder	4 cylinder
4	Transmission type	Manual
5	Fuel system	Diesel
6	Chassis number	LN 106-0136567
7	Maximum brake power	68kW@4000rpm
8	Maximum brake Torque	188Nm@2400rpm

3.4. Production of biodiesel

Extraction of crude oil was done in Addis Modjo edible Oil complex town and Transesterification of the biodiesel was conducted in ASTU chemistry department (laboratory) and chemical engineering department (laboratory). Performance testing of the biodiesel and the blends was done in ASTU automotive workshop of Mechanical and Vehicle engineering department. The chemicals used in the experimentation are like potassium hydroxide and methanol. Methanol 99.5% which is analytical grade and the basic catalyst potassium hydroxide (KOH) was used in the form of tablet for the Transesterification process.

Before the extraction of crude oil, it requires seed preparation and drying process in order to avoid impurities in the feed stock and avoid the water content of the seed which helps normal transesterification process to avoid saponification

3.4.1. Seed preparation

The processed raw linseed were requires for the preparation of seed by separating seed from its hard cover ; in the oil seed preparation which include; seed cleaning and seed drying.

3.4.2. Extraction of linseed oil

Oil was extracted at Addis Modjo edible oil factory by mechanical pressing. The amount of dried/ processed Linseed oil from flask plant for extraction is 20 kg which were crushed/ broken into small pieces and pressed mechanically in the machine and finally 5 liter linseed crude oil was extracted.

The following are the major steps for extraction of linseed oil

1. The separated seed from its hard cover and cleaned
2. The seed was added into machine and pressed, and then crude oil was extracted.
3. The extracted oil was collected by using plastic container
4. After the collection of the crude oil, it was goes in to the Mechanical engineering department for transesterification process.

Figure 3.2 Oil extraction process

3.4.3. Transesterification

Transesterification of linseed oil involves making triglycerides of linseed oil to react with alcohol which is methanol in the presence of a catalyst (KOH) to produce glycerol and fatty acid ester. For this process we used for each sample was 40 ml of methanol mixed with 2.30 gram of potassium hydroxide and 200 ml of linseed oil which is fully dissolved.

The transesterification process for producing linseed biodiesel:

1. The crude linseed oil was filtered and five liters of crude linseed oil was collected
2. 200ml of linseed oil is measured and taken in a flask per sample.
3. 40 ml of Methanol and 2.30 gm KOH were measured and taken into a flask for each sample.

Figure 3.3 Measuring the sample oil

4. Stirred the mixture until the KOH is fully dissolved in a Methanol. Do not use any more methanol or potassium hydroxide than is needed to have an efficient reaction. Most of the unreacted sodium hydroxide ends up in the glycerol layer and can be discarded or used to make soap.
5. The required sample of linseed oil was taken in a conical flask and preheated to 65^{o}C and the oil temperature by using thermometer

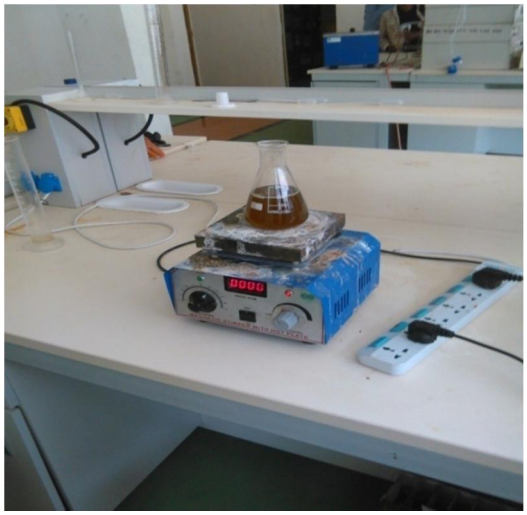


Figure 3.4 Heating of linseed oil on magnetic stirrer hot plate

6. Pour the mixture (KOH and Methanol) in to the oil and stirred for 1hr.

Then methanol (by volume) and KOH (by weight) was mixed and stirred in a separate conical flask. After that the stirred sample was added in the preheated linseed oil sample and again mixed properly by stirring.

This mixture was then constantly stirred for reaction time 60min at a temperature of 65^{O}C After this the stirred sample was taken out and was poured in a separating funnel to separate the glycerol from the methyl ester.

After 24 hours the glycerol was removed and separated to obtain the methyl ester.

Two layers are formed in the decanter.

i.e. bottom layer and top layer.

- ✓ In the bottom layer – glycerol and fatty acid
- ✓ In the top layer – ester (methyl ester)

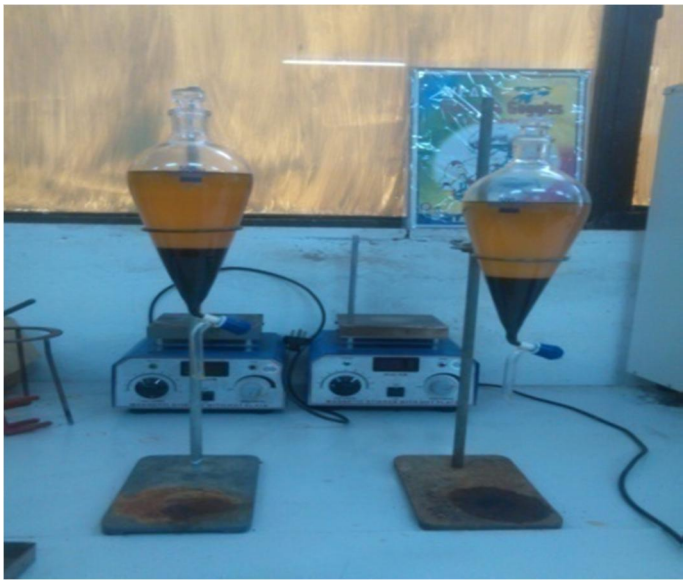


Figure 3.5 Oil into decanter and layer formation

Drain out glycerol and fatty acid from bottom layer through separator vessel.

Ester is remaining *i.e. biodiesel*

3.4.3.1. Washing Biodiesel

Unwashed biodiesel will not meet ASTM (American Society of Testing and Materials) standards. There are three techniques for washing biodiesel: agitation washing, mist washing, and bubble washing. The process of washing biodiesel involves mixing it with water. Water is heavier than biodiesel and absorbs the excess alcohol, sodium hydroxide, and soap suspended in it. After washing and settling, the water and the impurities in the water can be drained from the bottom of the container. Several wash cycles are generally needed. The first water drained off the bottom of the biodiesel will be milky, and the final wash water drained off will be clear. Excess sodium hydroxide in the biodiesel will form soap when mixed with water, and it takes a while for the soap to settle out. Depending on the method you use, it takes roughly as much water as biodiesel for a wash cycle. Initial washings must involve gentle mixing to minimize the formation of soap that will take time to settle out. However, you want the mixing to be thorough and for the water to be dispersed throughout the biodiesel. Agitation washing amounts to stirring water into the biodiesel, letting it settle, and draining it off. Mist washing is spraying a fine mist of water over the surface of the biodiesel. Tiny droplets of water fall through the biodiesel and pick up impurities on the way down. Bubble washing is done by putting a bubbler in a layer of water beneath the biodiesel in a container. As the bubbles rise they are coated with water, which

picks up impurities as it travels up and then back down through the biodiesel. All washes can be done after the initial settling time (18 hours) and after draining the glycerine layer, but you can get better results by waiting at least 36-48 hours or longer before the first wash, so that soaps and free glycerine have more of a chance to settle out.

3.4.3.2. Drying Washed Biodiesel:

The current conventional wisdom on dry fuel is that if it is 'clear'- referring to lack of haze, not color- it does not contain much water (in reality biodiesel will absorb some small and harmless amount of moisture from the atmosphere).Washed fuel will often look slightly cloudy or hazy. If you let it sit it will eventually drop or evaporate its water content. More importantly than these external drying aids, is the fact that the better-washed the fuel, the faster it will clear. If there aren't any soaps left to hold on to water, the water will settle out rapidly. We have made fuel that cleared almost immediately, and we think the factor that helped this was the number of times we washed it.

A test for water content is to weigh a sample, heat it until it passes the boiling point of water, then re-weigh to see how much water it has lost. Biodiesel contains 1200-1500 ppm water normally, this is the water absorbed from the atmosphere naturally.

We follow the following procedure to wash the biodiesel:

1. Wash the raw biodiesel using regular distilled water to remove impurities
2. Repeat washing process as required 3 to 4 times until water is mostly clears.
3. Biodiesel is allowed to settle until remaining water drops to the bottom.
4. Water was heated at 50^0C
5. One third volume of the biodiesel water was taken using syringe.
6. The biodiesel was filled in a decanter and hung on stand By using the syringe, the water was sprayed to the oil slowly.
7. Gently shaking the mixture.
8. The oil was left for 24 hrs hang in a decanter.
9. The water and soap settled at the bottom and was separated by opening the valve of the decanter.
10. Repeat washing until water became clear

Figure 3.6 Oil into decanter for washing and layer formation

The biodiesel was collected and heated by electric heater for 1hr at a temperature of 100^0C to evaporate the water left during washing process collecting the biodiesel and preparing for blending

Figure 3.7 Heating and drying the biodiesel

Figure 3.8 Collected biodiesel

3.5. Blending of Biodiesel

The blends were made on a volume basis and stored in glass bottles at room temperature. The biodiesel which is prepared by transesterification process from linseed seed oil and ethanol blended with conventional diesel fuel in proportion of 10%, 5% and 85% which is called B10,

i.e. 10% biodiesel E5 i.e. ethanol and 85% diesel fuel was conducted in diesel engine without any modification.

In this project the method used to blend the linseed biodiesel and ethanol with conventional diesel fuel is splash mixing type rather than inline mixing type because, bio-diesel is slightly heavier than conventional diesel fuel This allows use of splash blending by adding bio-diesel on top of diesel fuel for making bio-diesel blends. Bio-diesel should always be blended at top of diesel fuel. If bio-diesel is first put at the bottom and then diesel fuel is added, it will not mix.

3.6. Test fuels

The fuels used to test and blend in the experiment are: pure diesel, linseed biodiesel and ethanol.

Figure 3.9 Preparing the pure diesel fuel 85%

Figure 3.10 Blended fuel and Ethan biodiesel 10%

The blended fuels are; bio-diesel from linseed oil, ethanol and conventional fuel at the proportion of only 10%, 5% with 85%. Such blending procedures are given below:

- ✓ Collecting materials needed to blend the fuel.
- ✓ Cleaning the materials used to blend.
- ✓ Taking a cylindrical flask of one liter.
- ✓ Preparing and measuring blends of 1000 ml in amount.
- ✓ The blend B10 was prepared by taking 100 ml of biodiesel, E5 was preparing by taking 50ml of Ethanol and 850 ml of petro diesel.
- ✓ The blends were prepared by volume

3.7. Characterization

Due to the time constraints only four properties of the biodiesel was measured at Ethiopian petroleum supply enterprise in Addis Ababa and the apparatus for measurement and test result is listed below in the table

A. Properties and apparatus

1. Density, g/ml measured by Automatic digital density meter
2. Flash point (PMCC), ^{0}C measured by flash point tester uses thermometer
3. Clouded point, ^{0}C measured by Biosince titration
4. Kinematic viscosity measured by viscometer
5. Total Acidity, mg KOH/g measured by Biosince titration

Figure 3. 11Viscometer

Figure 3.12Automayic digital density meter

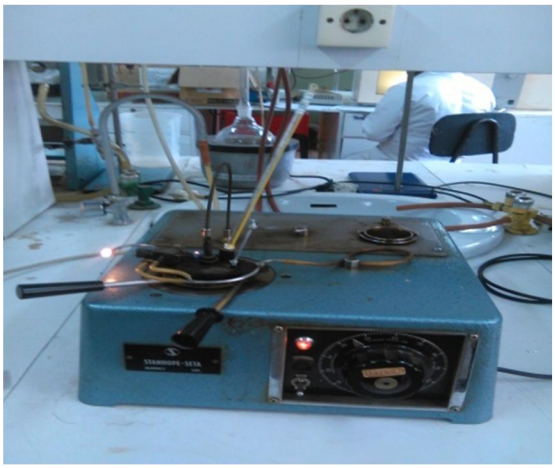


Figure 3.13 Flash point tester

Figure 3.14 Biosince titration

Measuring the viscosity of sample fuel measuring the density of the fuel with a digital the (Viscometer).al density meter.

Table 3.4 Fuel characteristics

Property	pure Diesel	Pure Linseed Biodiesel	Ethanol	Test method (ASTM)	EPSE Diesel limits	ASTMD6751limitfor B10
Density@15^{0}C,g/ml	0.8426	0.8985	0.7988	D4052	Reported	
Density@20^{0}C,g/ml	0.8390	0.951	-	D4052	Reported	
Flash point ^{0}C	84	110	-	D93	Min.60	Min93
Cloud point^{0}C	+4	-1	-	D2500	M+5	reported
Kinematic viscosity at 40 ^{0}C	3.5	5.1	-	D445	1.9-5.5	1.9-6
Total acidity, mg KOH/g		0.14		D974		

3.8. Performance testing

The performance of fuel was tested using chassis dynamometer in four stroke 3L diesel Toyota vehicle available in automotive work shop in ASTU. The blend of biodiesel is 10% (B10),5% (E5) biodiesel(linseed10% with diesel and compares with pure diesel. The performance of the engine with blend of biodiesel, ethanol and petro diesel can be evaluated by measuring torque, power and its fuel consumption at different speeds. The power and brake specific fuel consumption can be calculated.

Three sets of engine experiments were performed to evaluate the power. The experiments were conducted for conventional diesel 85%, 10% biodiesel and Ethanol and conventionalfuel90%and linseed bio diesel 10%. In all settings, the experiments were conducted as for the steps given below. Fuel blends were prepared by volume.

The engine fuel tank was cleaned and filled with the fuel to be tested.

The engine was run with the test fuel for about five minutes to get warm up and stabilize.

After warming up the test was conducted for pure diesel engine at different test speeds then different parameters has been read from the dynamometer

And such parameters tractive force and power at the rear wheel were recorded at different speeds at equal intervals in the speed range.

Figure 3.15 Vehicle on Chassis dynamometer

Figure 3.16Measuring fuel consumption

3.9. Chassis dynamo meter

Chassis dynamometers are very popular to run some quick tests for installed power and check out the chassis and drive train. They are quick to use but have some problems that should be made clear before you start down that direction. If you plan on testing a few sets of exhaust components or any bolt-on parts that might take more time than if the testing was done on an engine dyno, so do some planning and think about what you want to accomplish.

Chassis dynamometers come in all sorts of designs and configurations but there are some things that are common to all. Most designs test a vehicle that powers a roll or rolls for all wheel drive types. Most can provide some common numbers for horsepower but not all measure torque to do so. Basically there are two general types of chassis dynos – inertia only and those that measure torque with either an electric load or even a mechanical brake. All have to get rid of the heat from the vehicle and the dyno as well.

Basic Configuration of Chassis Dynamometers

A chassis dynamometer measures the power from the engine through the wheels. As the tractive force of the vehicle tires is transferred through the rollers, the chassis dynamometer controls the speed and resistive force of the rollers. For emission testing the dynamometer simulates the

vehicle rolling resistances during the tests to provide the same load on the engine as when driving the vehicle on the road.

Terms of Engagement

Such terms as torque, horsepower, speed, roll speed, dyno inertia, heat load, power capacity, speed capacity, and many others can easily roll off of the tongue or rattle from a keyboard. It takes a bit more to understand what all those things mean. Lest this short article end up being something from a text book, let's stay with the quick and easy method.

Torque

Torque is a twisting motion and is typically expressed in lbs-ft. Notice this is not ft-lbs! Although everyone commonly uses incorrect units for description of this very important item, the proper reference is indeed pounds feet (lbs-ft).

Speed

Most common references in the US for speed is miles per hour (MPH). Speed can also be in feet per second such as 88 ft/sec = 60 MPH.

Roll Speed

Refers to the speed of the roll(s) on the chassis dynamometer and can be directly related to the vehicle speed or simply given as roll RPM. Because of the friendly relationship of round things to π or 3.1416, it is easy to calculate the circumference of the roll by measuring the diameter and multiplying that by π. That gives us the opportunity to verify some dyno basics.

Heat Load

Is not the number of cops per city block. The term has to do with the heat that the test vehicle and the dyno must dissipate to the atmosphere or the room the dyno and vehicle are in. In short it takes a lot of moving air to keep the overall packages cooled down. Normally you never consider that as you drive along at various speeds the moving air carries heat away and you can enjoy the scenery. Or if your cooling system is overloaded from traffic being slow it might cause the engine to overheat. At high power levels the heat load increases hence the requirement for a very large fan or maybe more. That is why most popular chassis dyno tests are just quick spurts that make it easier

on the whole operation. By the way a normal expression for a heat load is in BTUs (British Thermal Units) per time. In order to put this in perspective, if you wanted to test a vehicle that might produce 500Hp at the drive wheels, that would easily be a total heat load of approximately 1500Hp (3.8 million BTUs per hour!) that must be dissipated into the atmosphere from the cooling system of the vehicle and the drive train, exhaust system and the tire patches and the dyno itself. Of course that varies somewhat by how much you allow the temperature across the room to rise. Perhaps this stuff is a little more complex than you thought.

Speed Capacity

Often a mechanical limit set by the manufacturer such as 150MPH or some other number that should not be exceeded for safety's sake.

Power Capacity

Also a number set by the manufacturer that is fundamental to the capability of the drive tires. This capacity number is quite often higher than most vehicles can even contest. The term is also normally associated with a speed such as 500 Hp at 120 MPH or something similar.

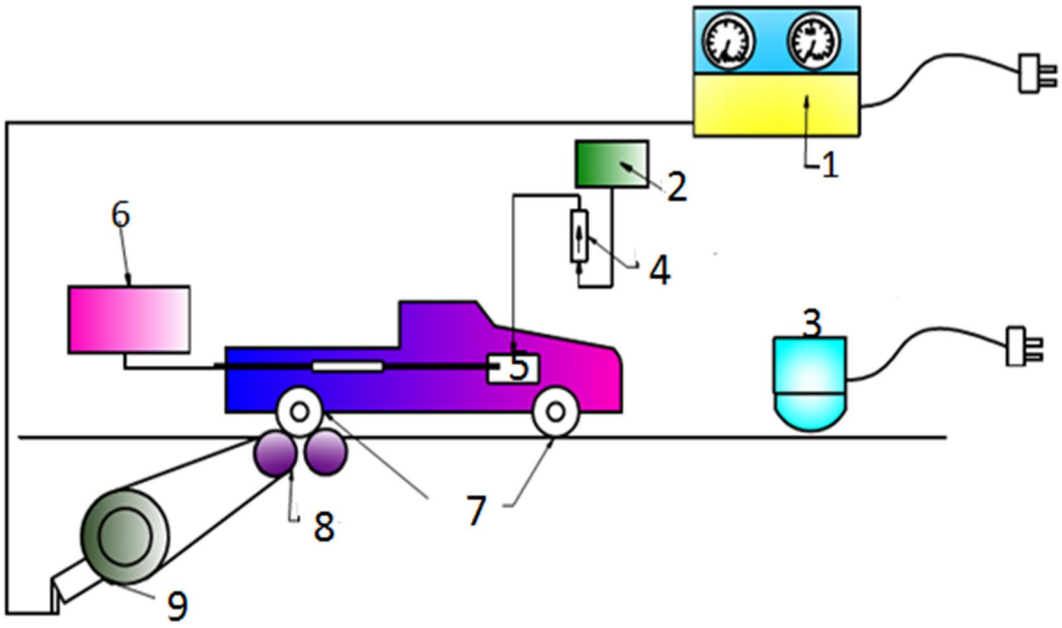
Portable unit specification

- Roller size: 8.65 in.(220 mm) diameter
- Roller length: 28.7 in (730 mm)
- Roller to Roller spacing: 17.4 in (444 mm)
- Tracking unlimited
- Maximum Axle Weight: 6000 ibs
- Power absorber: eddy current brake.
- Peak Power absorption: 50 hp continuous.
- Peak speed: 100 mph.
- Mechanical inertia simulation: up to 1000 ibs per side (2000 ibs. Total).
- Electrical inertia simulation: up to a maximum 5500 ibs.
- Method of movement: 360 degrees Rotation.
- Dimension: 66.5 in Lx 28.3 in .Wx24.4 in. H(1690 mm Lx718 mm Wx620 mm H).

3.10. Vehicle testing procedure

For obtaining the performance, the engine is started with diesel and the engine is in its appropriate operating condition by applying full throttle and reaches its maximum power. The vehicle was driven on the chassis dynamometer and the tractive force (kN) and wheel power (kW) which is measured at test speed of starting from 25 km/hr which is a minimum speed on the sun Road-a-Matic XII chassis dynamometer. The experiment was conducted in first gear, second gear, third gear and fourth gear. The time taken for the consumption of around ten grams of fuel was recorded. Experiment first the performance of conventional diesel fuel was tested and then the blend.

Experiments were performed with three different fuel (with conventional diesel, ethanol and with linseed biodiesel) fuels starting from 25 km/hr, 30 km/hr, 35 km/hr, 40 km/hr,…100km/hr with 5 km/hr intervals; of full load for different speed whose fuels were pure diesel and biodiesel (blend of 10% biodiesel 5% with 85% diesel)a and biodiesel B10%with 90% diesel .Therefore, in this



1.Measuring gauge
2.Fuel tank
3.Blower
4.Rota meter
5.Engine
6.Exhaust gas Analyzetr
7.Tier
8.Rotor
9.Driver

Figure 3.17 Vehicle on chassis dynamometer and testing equipments

4. RESULTS AND DISCUSSIONS

4.1. Extraction of linseed oil

Oil was being extracted from seed of linseed plant using mechanical press oil extraction method in Addis Modjo edible oil complex private limited company which is found in Modjo town. During the extraction of oil five litters (5 L) of oil is extracted from twenty kilograms (20 Kg) of linseed.

4.2. Biodiesel Yield

The production of biodiesel was done by transesterification reaction process using alcohol and catalyst (methanol and KOH). After washing and neutralizing three times by heating distilled water at 50^0C. Finally, drying the biodiesel by heating at 100^0Cand production yield is found to be 90 %.

4.3. Transesterification Process of linseed seed methyl ester

Transesterification of linseed oil is done to reduce its viscosity by separating glycerol content from it. The separation of glycerol is depends on by the parameters such as molar ratio, catalyst type, catalyst concentration, reaction time, reaction and temperature.

Table below shows parameters used in this experiment.

Table 4.1Transterification process

Amount of linseed oil (ml)	Molar ratio	Concentration of catalyst & type (KOH) %	Concentration of alcohol & type (Methanol) in ml	Reaction time in minute	Reaction temperature in ^{0}c	Settling time in hr
200	1:5	1.5	40	60	65	24

The effect of KOH concentration was studied in the range of 0.5 - 1.5% (weight of KOH/weight of oil) which is taken in this experiment is 1.5 % getting 2.30 gm of KOH for 200 ml of the mixture. It was found that the ester recovery increases as the amount of catalyst increases from 0.5-1.5%. Ester recovery decreases as KOH concentration decreases below 0.5% .If ester recovery increase above 1.5% KOH concentration the high soap formation occurred.

4.4. Performance Testing Result

Biodiesel from linseed oil was produced at the ASTU chemistry department laboratory and chemical engineering department which is replacement for conventional diesel fuel. Therefore the research was mainly concentrated on investigating engine performance at B10%, E5% blend ratio for four engine speeds by using Sun ROAD –A- MATIC XII chassis dynamometer. As the initial step 10% of biodiesel 5% ethanol were measured and blend with 85% of diesel fuel and also 10% biodiesel was measured to blend with 90% of diesel.

Then, after blending the test is begin with pure diesel to compare with biodiesel by evaluating torque power and fuel consumption. The chassis dynamometer is capable of measuring the power output and tractive force applied at the drive wheels.

When the performance is tested engine speed, brake torque, brake power and the flow rate of fuel are not registered directly. That means, brake torque is calculated from the wheel torque which is resulted from tractive force. Brake power was calculated from the brake torque and engine speed. Also the brake specific fuel consumption (bsfc) was calculated from the mass flow rate and brake power.

Tractive effort and wheel power

Tractive force is the force available at the contact between the rear wheel tires and road and which was recorded at the drive wheels on chassis dynamometer used to determine the torque produced by the engine. The measured value of tractive effort (F) in kN of diesel from chassis dynamometer is used for calculating the torque at the rear wheel and further also the brake torque.

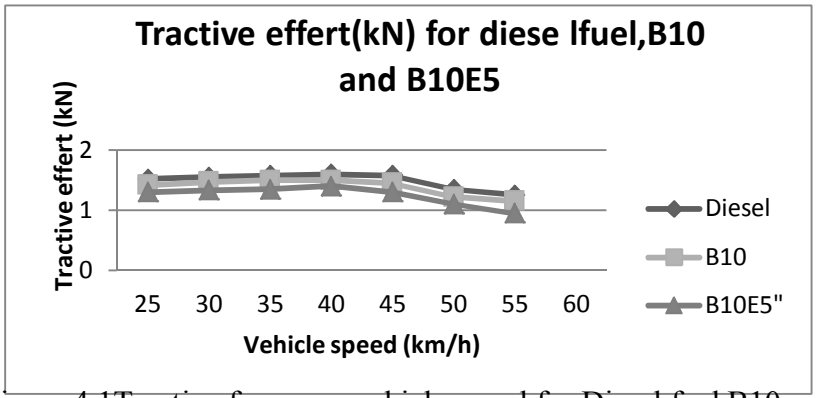


Figure 4.1Tractive force vs. vehicle speed for Diesel fuel,B10 and B10E5

The tractive force result is used to calculate the wheel torque, which used further to find the brake torque using the following formula.

$F = \frac{Tw}{r}$……..(1)

$T_{w=} F^{x} r_{w}$……..(2)

Where:-

$\mathbf{T_w}$ = wheel torque

F = Tractive effort

r_w =wheel radius

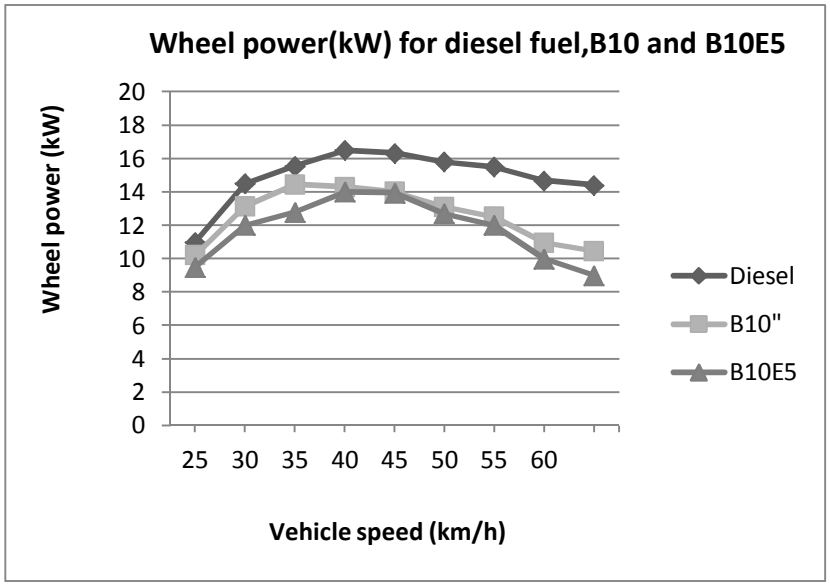


Figure 4.2 Wheel power vs vehicle speed for diesel fuel,B10 and B10E5

The tractive force and wheel power is reads directly from the chassis dynamometer and shows the relationship between tractive efforts, wheel power with vehicle speed using different gear ratios. The value of tractive effort is used to calculate the wheel torque and the brake torque.

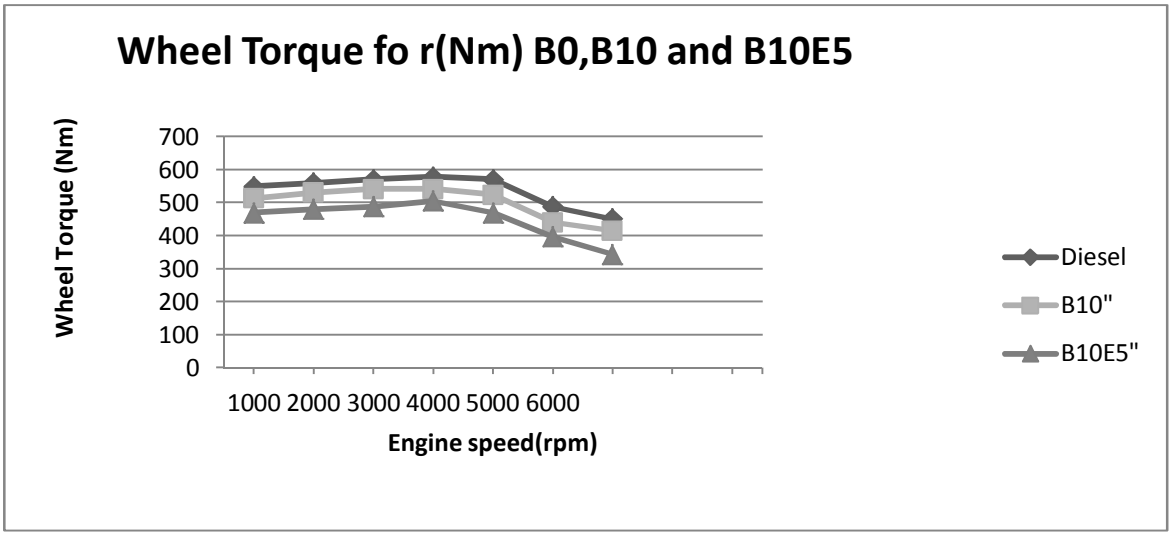


Figure 4.3 Wheel torque vs vehicle speed for diesel fuel,B10 and B10E5

Brake torque (T_b): brake torque is the turning force at the engine and it is calculated

By using equation (2) from the above wheel torque was calculated, the brake torque will be finding by using below equation

$$T_w = (g.r \times a.r)\eta t \times Tb \quad \ldots\ldots(3)$$

$$T_b = \frac{Tw}{(g.r^{x}a.r)^{x}\text{Mechanical Efficiency}} \quad \ldots\ldots(4)$$

Where:-

Tw = torque at rear wheels

g.r = gearbox gear ratio

a.r = back axle ratio

ηt = overall transmission efficiency

Tb = brake torque

The vehicle (Toyota Hilux model 3L engine) has a 5 speed transmission with the following gear ratios:

Table 4.2 Vehicle gear ratio

Gear	1st	2nd	3rd	4th	5th	Final drive
Gear ratio	3.901	2.432	1.654	1	0.812	4.544
Efficiency	0.80	0.825	0.85	0.87	0.90	0.92

The chassis dynamometer used for the test does not have engine revolution counter, it rather displays wheel speed in Km/hr. It is therefore necessary to calculate the engine speed (N) from the wheel speed.

The relationship between engine revolution (N) and vehicle speed (V) depends on the overall gear ratio. The engine revolution and vehicle speed can be related with the following expression:

$$\frac{2\pi N}{g.r^{x}a.r} = \frac{1000\ V\ (\frac{km}{hr})}{60} \quad \text{.....(5)}$$

$$N = \frac{V^{x}g.r^{x}a.r^{x}1000(\frac{rev}{min})}{CR^{x}60} \quad \text{.....(6)}$$

$$N = \frac{\mathbf{2.65^{x}\ V^{x}g.r^{x}a.r^{x}(\frac{rev}{min}}}{\mathbf{r}} \quad \text{.....(7)}$$

Where:

CR = the driving wheel circumference in m = 2π x tyre radius (r)

N = the engine speed in rpm

g.r = gear box ratio

a.r = back axle ratio

r = the radius of the wheel is 0.361m

Therefore, using equation (7) calculating the engine speed in rpm and the vehicle is driven with diesel fuel in all gear with full throttle, the engine is running at its maximum speed. Tractive force for pure diesel, linseed biodiesel and ethanol increases when the vehicle runs with the second gear and as the vehicle speed increases the tractive effort will be decreases.

After the value of engine speed are found, brake torque versus engine speed graph having the following result will be constructed.

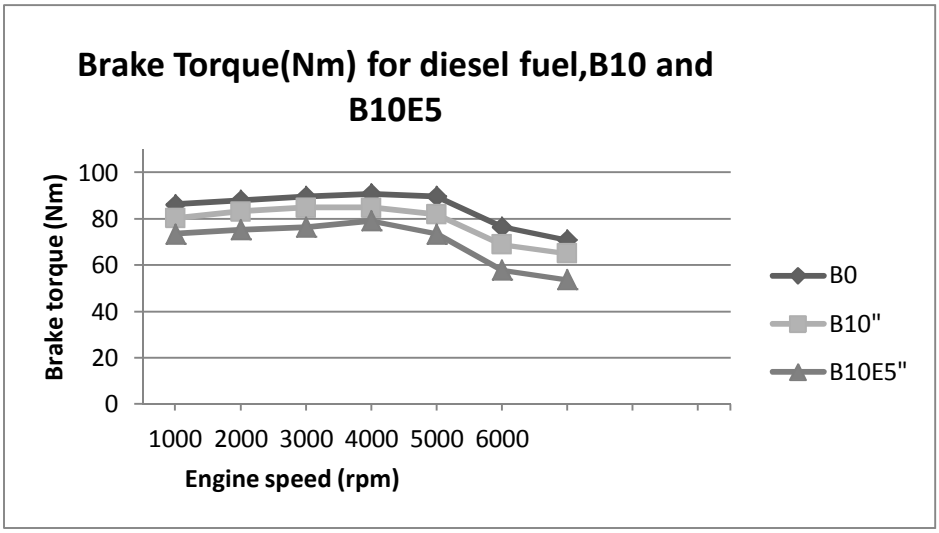


Figure 4.4 Brake torque vs engine speed for diesel fuel, B10 and B10E5

From the above curve observed that the torque increases with the increasing of speed up to 4554.91 rpm and decreasing further with increase in speed. Therefore the maximum torque has been achieved around 4554.91 rpm. It is similar for blend fuel

Brake power (P_b) : brake power is the power output at the engine which was calculated from brake torque and engine speed$Pb = \frac{2\pi TN}{60*1000}$----------(8)

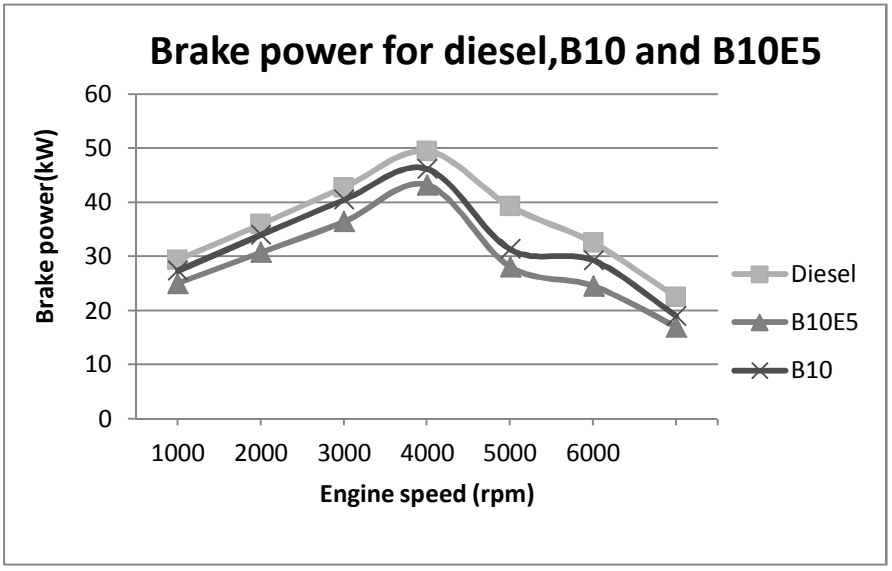


Figure 4.5 Brake power vs engine speed of Diesel, B10and E5

The above curve observed that the power with the blended of B10 and B10E5 were less by 4.85% and 9.19% respectively as compared to conventional diesel fuel

Brake specific fuel consumption (BSFC)

In engine tests, the fuel consumption is measured as a flow rate; mass flow per unit time (ṁf) which is uses the specific fuel consumption (bsfc) the fuel flow rate per unit power output

Specific fuel consumption (sfc)=$\frac{\boldsymbol{mass\ flow\ rate}}{\boldsymbol{Power}}$ (9)

Brake specific fuel consumption (bsfc) =$\frac{\textbf{mass flow rate}}{\boldsymbol{Brake\ power}}$. (10)

For calculating the bsfc first the mass flow rate of the fuel is determined, the brake specific fuel consumption can be calculated using equation below.

$$\textbf{bsfc} = \frac{mf\left(\frac{gm}{se}\right)^{x}3600}{Pb}\left(\frac{gm}{kwhr}\right) \quad (11)$$

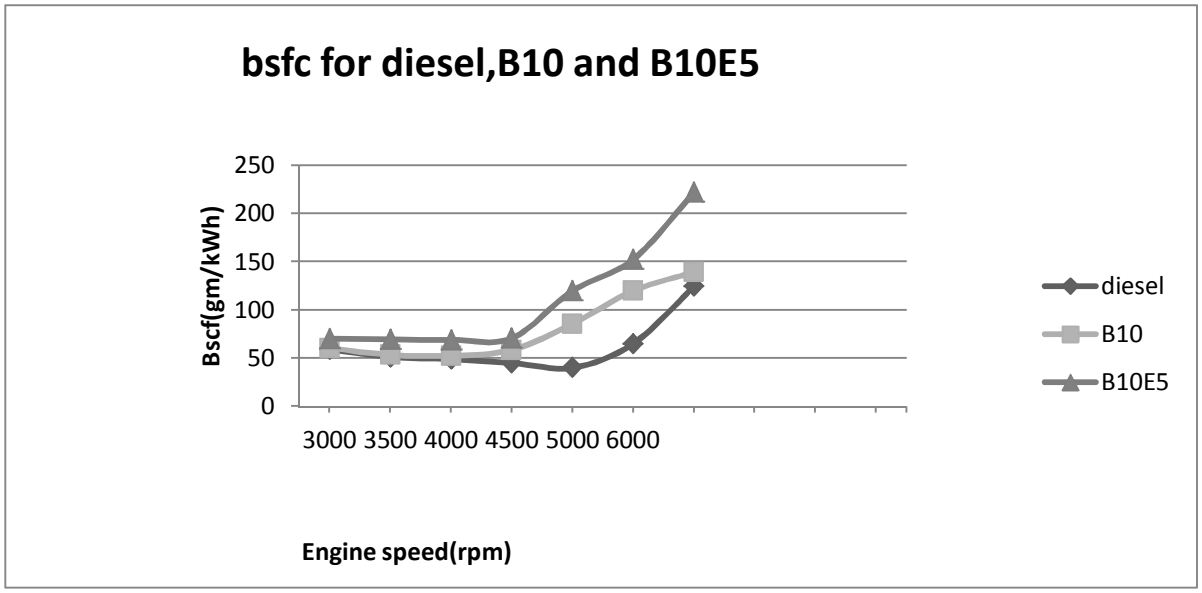


Figure 4.6 bsfc Vs engine speed for Diesel fuel, B10 and B10E5

The maximum bsfc and the least bsfc of 130 is found at 6506.13 rpm &at 3903 rpm when the vehicle running pure diesel fuel and blend fuel of B10 and B10E5

Performance curve:

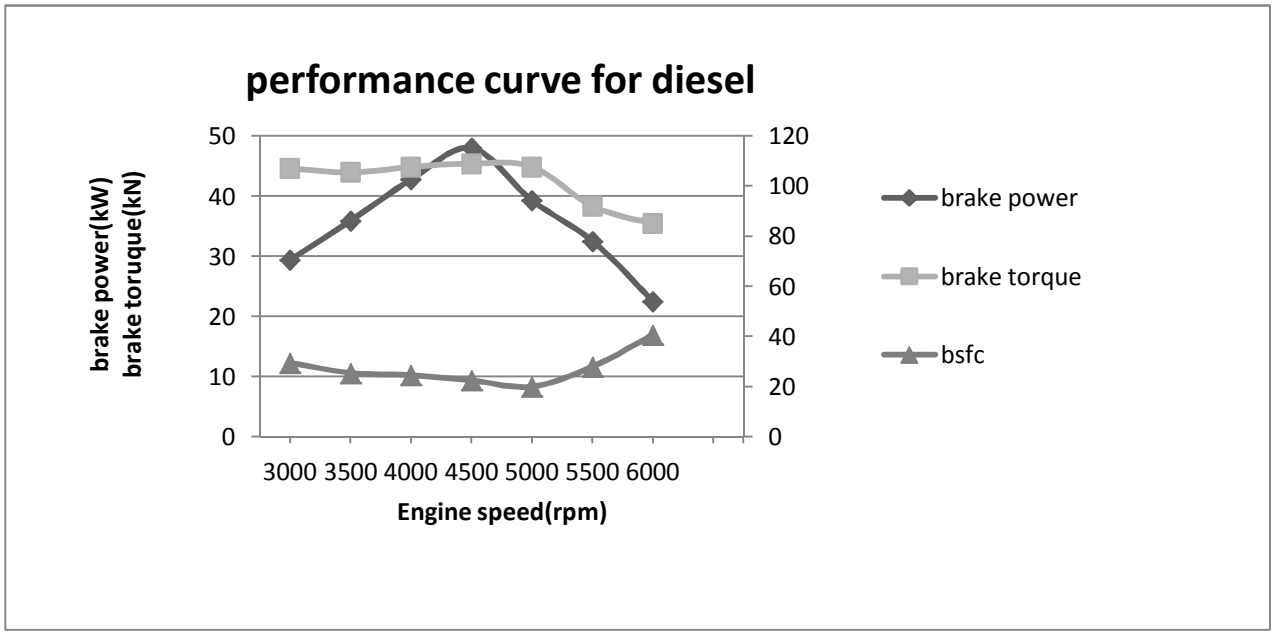


Figure 4.7Performance curve for Diesel

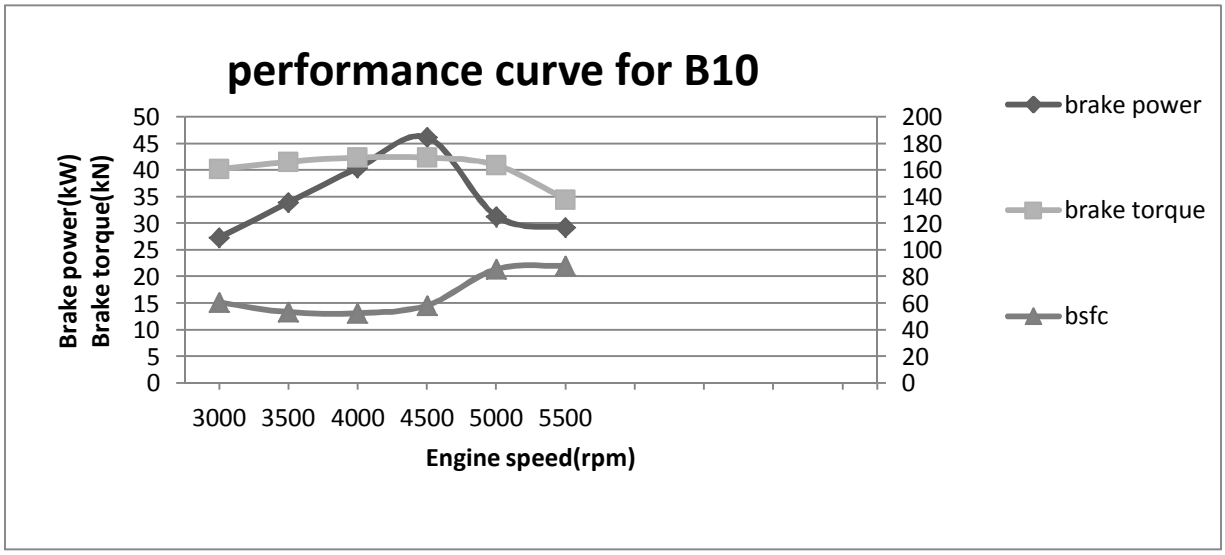


Figure 4.8 Performance curve for B10

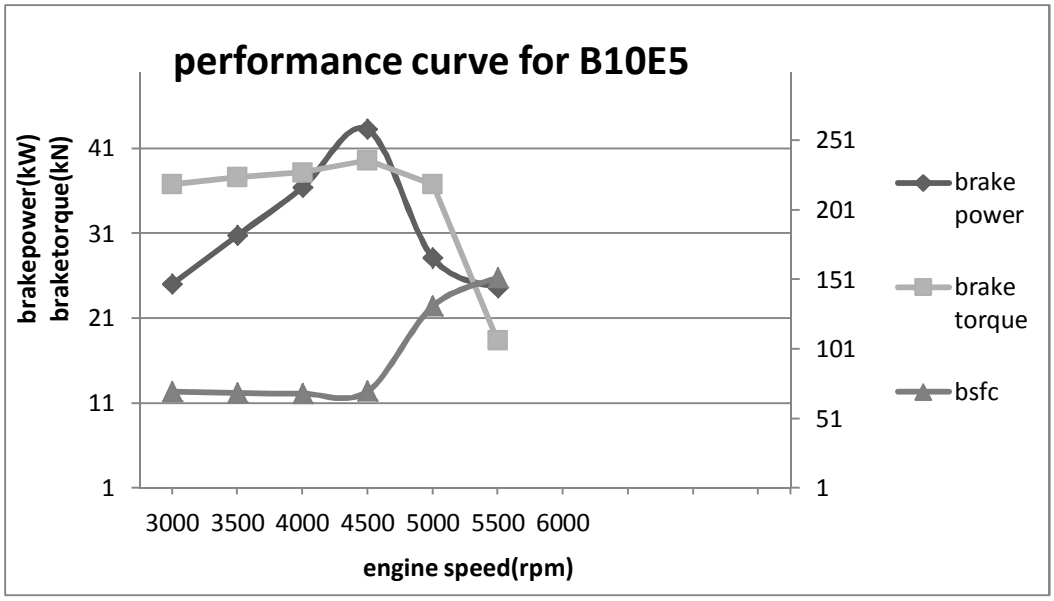


Figure 4.9 Performance curve for B10E5

The above curves shows that the performance of fuel which is by comparing the conventional diesel with the blended fuel (linseed biodiesel, linseed biodiesel ethanol). This comparison was done by comparing the brake power, brake torque, and fuel consumption with engine speed. As a result the maximum brake torque decreases by 3.19% for B10 and 6.01% for B10E5 and brake power decreases by 4.85% for B10 and 9.19% B10E5 were compared to conventional diesel fuel and brake specific fuel consumption is increases with the increase in engine speed. This will be the reason for the high heating value with its high viscosity. Depending on the experimental observation B10 and B10E5 were better at low and medium vehicle speed.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The main aim of the study was to test the performance of diesel on vehicle compare with diesel-biodiesel and ethanol as a fuel without any major modification. For starting purpose conventional fuel was used.

For oil extraction it is better to use mechanical pressing than chemical and enzymatic extraction. The mechanical extraction method is very much cheaper, higher value of oil, cake used for animal feeds, safer and less complex to operate than the other extraction methods. .

In this work transesterification reaction was carried using the linseed oil. The quantity of potassium hydroxide catalyst for optimal biodiesel yield of 90% was 2.3 gm per sample at reaction time of one hour, reaction temperature of 65^0C and volume ratio of oil to methanol as 5:1. The trans-esterification reaction is affected by molar ratio of glycerides to alcohol, catalysts, reaction temperature, reaction time and free fatty acids and water content of oils.

Based on the experimental results, the following conclusions are drawn.

Maximum brake torque decreases by 3.19% for B10 and 6.01% for B10E5 and brake power decreases by 4.85% for B10 and 9.19% B10E5 were compared to conventional diesel fuel and brake specific fuel consumption is increases with the increase in engine speed. Depending on the experimental observation B10 and B10E5 were better at low and medium vehicle speed.

Ethanol has good oxygenate content and effect on lowering the viscosity of the blend, which lead to an improvement in the combustion process reduce particulate maters but due to its low flash point it is difficult to handle and use.

The brake power, brake torque of our biodiesel was less when compared with conventional diesel fuel and fuel consumption was increase. But according to estimation using the analytical equation to emission produced from the combustion of diesel fuel is high when compared with biodiesel.

5.2. Recommendations

The study of linseed oil has been used as a resource to obtain biodiesel, which gives opportunities for generation of rural development and increasing income. So the development on additional fuel property blending conditions, engine performance and emission tests are necessary. This project was done only with the blend of B10.E5 and checks the performance comparing with the conventional diesel. The future will conduct with other blends with the addition of additives which is improving the performance of linseed biodiesel as alternative fuel and increasing the production of linseed.

Ethiopia is good in agricultural sector; the plantation coverage of linseed is located different areas i.e. the principal linseed growing regions in Ethiopia are located at altitudes between 1800 and 2800 meter above sea level (masl), although it occasionally grows at altitudes as low as 1680 masl or as high as 3430 masl Arsi, Bale, Chercher Mountains, Eastern Welega, EasternGojam, Tigray, Southeast Wello, and Shoa are the major areas of production and South Gondar,Kefa, Gemogofa and Illubabor are small-scale production areas in Ethiopia. As a result, the increased awareness of the negative environmental factors associated with petroleum fuels and a desire to move to renewable fuels, biodiesel production from linseed is growing significantly. However, it represents the fossil fuel which in the reduction of environmental aspects.

The performance test is done on a chassis dynamometer which is found in the department of Mechanical and Vehicle Engineering. The engine dynamometer is not functional but chassis dynamometer is functional, therefore the accuracy of the measurement is sufficient to measure different speeds and fuel consumption. The byproduct of linseed biodiesel could be used for different purposes. The cake used for animal feeds after mechanical pressing. The soap could be used as raw material for cosmetic industry. Therefore biodiesel industries shall use the byproducts in order to compensate the biodiesel price.

5.3. Educational Implication

The objective of the National TVET strategy is to create a competent, motivate, adaptable and innovative workforce in Ethiopia contributing to poverty reduction and social & economic development through facilitating demand driven, high quality technical and vocational education

and training, relevant to all sectors of the economy, at all levels and to all people in need of skill development transferring new technologies. (National TVET strategy, MOE, 2006).

The primary objective of all technical and vocational education and training programmer is the acquisition of relevant knowledge, practical skills and attitudes for gainful employment in a particular trade or occupational area.

There are many benefits of investing in vocational education and skills.

The little roles are discussed below.

- Creating a pool of qualified people with the knowledge and skills to contribute significantly to economic development, to be entrepreneurial, develop science and technology, deliver basic services, and to be enlightened leaders.
- Enabling countries to compete in an era of globalization and knowledge. Investment in Vocational education is associated with greater export-led growth than primary education. (Wood and Mayer 1999)
- Expanding choices and increasing personal and work-related kills.

The objective of this project is to show how biodiesel can be produced from linseed and usage of biodiesel-ethanol and diesel blends in diesel engine.

- Increase National incomes by reducing fuel importing amount
- Give job opportunity to many people by participating biodiesel production.
- Increase the capacity of small Industry, heavy Industry & machines which works by fuel.
- Increase small enterprise by giving chance to cultivate linseed.
- Increases the country research scope.

From the above important advantages it requires working with TVET institution on either short term training or long term training. The institution should support the company or small enterprises by providing training for the workers to fill the skill gap, cultivation, production, and safety, wisely using of resource, technical advancement and follow up. These indicate TVET institution needs to provide improved curriculum for coming generation based on labor market especially on Biodiesel production and blending technology, and testing their performance in engine.

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APPENDIX

Appendix 4.1 Tractive force for diesel fuel

Tractive force for Diesel (kN)				
Vehicle speed (km/hr)	1st	2nd	3rd	4th
25	2.75	2.2	1.52	1.24
30	1.4	1.85	1.55	1.3
35	0.5	1.55	1.58	1.35
40		1.1	1.6	1.34
45		0.8	1.58	1.3
50			1.35	1.25
55			1.25	1.12
60				0.9
65				0.75.
70				0.60

Appendix 4.2. Tractive force for B10

Tractive force for B10 (kN)				
Vehicle speed (Km/hr)	1st	2nd	3rd	4th
25	2	2.18	1.42	1.16
30	1.2	1.70	1.47	1.2
35	0.38	1.33	1.5	1.25
40		1	1.5	1.29
45		0.73	1.45	1.22
50			1.22	1.16
55			1.15	1
60				0.75
65				0.55
70				0.50

Appendix 4.3.Tractive force for B10E5

Tractive force for B10E5(kN)				
Vehicle speed (Km/hr)	1st	2nd	3rd	4th
25	1.95	2	1.3	1
30	1.1	1.5	1.33	1.1
35	0.33	1	1.35	1.2
40		0.90	1.4	1.19
45		0.65	1.3	1.18
50			1.1	1.1
55			0.95	0.85
60				0.74
65				0.50
70				0.45

Appendix.4.4.Wheel power for diesel

Wheel power for diesel (kW)				
Vehicle speed (Km/hr)	1st	2nd	3rd	4th
25	6	14	11	10
30	4.5	16	14.5	12.5
35	3.6	16.44	15.55	13.5
40		17.15	16.5	14.5
45		17.26	16.33	15
50		15.55	15.8	14.9
55		15	15.5	16.2
60		14.5	14.68	15
65		12	14.4	13.7
70				12.8

Appendix 4.5 .Wheel power for B10

Wheel power for B10 (kW)				
Vehicle .speed (Km/hr)	1st	2nd	3rd	4th
25	5.15	12.78	10.2	9.25
30	3.89	14.43	13.15	10.55
35	3	15.45	14.45	12.78
40		15.78	14.30	13.25
45		16	14	13
50		13.35	13.11	12.86
55		13.5	12.50	12.5
60		12.45	10.95	12.25
65		8.55	10.45	12
70				11.65

Appendix.4.6 .Wheel power for B10E5

Wheel power for B10 E5 (kW)				
V.speed (Km/hr)	1st	2nd	3rd	4th
25	4.8	12	9.5	8.33
30	3	13	12	9.64
35	2.7	12.9	12.8	12
40		14.85	14	12.95
45		15	13.95	13
50		12.54	12.7	12.86
55		11.87	12	12
60		10.90	10	12
65		8.55	9	11.66
70				10.45

Appendix. 4.7 Wheel Torque for diesel

Wheel torque for diesel (Nm)				
Engine speed (rpm)	1st	2nd	3rd	4th
3253.07	992.75	794.2	548.72	447.64
3903.68	505.4	667.85	559.55	469.30
4554.29	180.5	559.55	570.38	487.35
5204.91		397.1	577.76	483.74
3650.5		324.9	570.38	469.30
4056.1			487.35	451.12
3034.4			451.12	404.32
2001.4				324.9
2168.2				252.7
2334.9				216.6

Appendix. 4.8 Wheel Torque for B10

Wheel torque for B10 (Nm)				
Engine speed (rpm)	1st	2nd	3rd	4th
3253.07	722	786.98	512.62	418.76
3903.68	433.2	613.7	530.67	433.2
4554.29	137.18	480.13	541.5	451.25
5204.91		361	541	465.69
3650.5		263.53	523.45	440.42
4056.1			440.42	418.76
3034.4			415.15	361
2001.4				270.75
2168.2				198.55
2334.9				180.5

Appendix. 4.9. Wheel Torque for B10E5

Wheel torque for B10 E5 (Nm)				
Engine speed (rpm)	1st	2nd	3rd	4th
3253.07	703.95	722	469.3	361
3903.68	397.1	541.5	480.13	397.1
4554.29	119.13	361	487.35	433.2
5204.91		324.9	505.4	429.59
3650.5		234.65	469.3	425.98
4056.1			397.1	397.1
3034.4			342.95	306.85
2001.4				324.9
2168.2				180
2334.9				162.45

Appendix . 4.10. Brake torque for diesel fuel

Brake torque for diesel fuel				
Engine speed (rpm)	1st	2nd	3rd	4th
3253.07	70.01	87.17	86.27	114.77
3903.68	35.64	73.30	87.97	119.11
4554.29	12.72	61.42	89.68	123.69
5204.91		43.58	90.84	122.77
3650.5		35.66	89.68	119.11
4056.1			76.62	114.49
3034.4			70.93	102.61
2001.4				82.46
2168.2				63.97
2334.9				54.83

Appendix. 4.11 .Brake torque for B10

Brake torque for B10				
Engine speed (rpm)	1st	2nd	3rd	4th
3253.07	39.71	86.38	80.34	106
3903.68	23.82	67.36	83.17	109.67
4554.29	7.54	52.70	84.87	114.24
5204.91		39.62	84.79	117.89
3650.5		28.92	82	111.49
4056.1			69	106
3034.4				91.39
2001.4				68.54
2168.2				50.26
2334.9				49.86

Appendix. 4.12 .Brake torque for B10E5

Brake torque for B10E5				
Engine speed (rpm)	1st	2nd	3rd	4th
3253.07	49.64	79.25	73.55	91.39
3903.68	22	59.44	75.25	100.53
4554.29	8.40	39.62	76.38	109.6
5204.91		35.66	79.21	108.75
3650.5		25.57	73.55	107.84
4056.1			57.85	100.53
3034.4			53.75	77.68
2001.4				67.63
2168.2				52.26
2334.9				41.12

Appendix 4.13 Brake power for diesel

Brake power for Diesel (kW)				
Engine speed (rpm)	1st	2nd	3rd	4th
3253.07	23.84	29.69	29.39	39.09
3903.68	14.56	29.69	35.95	48.69
4554.29	6.06	29.29	42.77	58.99
5204.91		23.75	49.51	66.91
3650.5		13.73	39.28	45.53
4056.1			32.54	48.36
3034.4			22.53	32.60
2001.4				17.28
2168.2				14.58
2334.9				12.91

Appendix. 4.14. Brake power for B10

Brake Power for B10(kW)				
Engine speed (rpm)	1st	2nd	3rd	4th
3253.07	13.52	29.42	27.36	36.11
3903.68	9.73	27.53	33.99	44.83
4554.29	3.59	25.13	40.47	54.48
5204.91		21.59	46.21	64.25
3650.5		11.05	31.34	42.62
4056.1			29.30	45
3034.4			19	29
2001.4				14.36
2168.2				11.41
2334.9				12.19

Appendix. 4.15 Brake power for B10E5

Brake Power for Blend fuel B10E5 (kW)				
E.speed (rpm)	1st	2nd	3rd	4th
3253.07	16.90	26.99	25.05	31.13
3903.68	8.99	24.29	30.76	41
4554.29	4	18.89	36.42	52.27
5204.91		19.43	43.26	59.27
3650.5		9.77	28.11	41.22
4056.1			24.57	42.7
3034.4			17	24.68
2001.4				14.14
2168.2				11.8
2334.9				10

Appendix.4.16. bsfc of diesel fuel

bsfc of diesel fuel (gm/kWhr)			
Engine Speed (rpm)	time (sec)	mf	bsfc
3253.07	20	0.61	73.49
3903.68	20	0.60	61.70
4554.29	20	0.67	56.39
5204.91	20	0.67	48.71
3650.5	20	0.73	27.49
4056.1	20	0.74	81.86
3034.4		0.78	124.63
2001.4			
2168.2			
2334.9			

Appendix.4.17 bsfc of B10

Bsfc for B10 (gm/kWhr)			
Engine Speed (rpm)	time (sec)	mf	bsfc
3253.07	20	0.46	60.54
3903.68	20	0.503	53.27
4554.29	20	0.59	52.48
5204.91	20	0.75	58.42
3650.5	20	1.1	85.69
4056.1	20	1.101	126.47
3034.4		1.103	135.52
2001.4			
2168.2			
2334.9			

Appendix.4.18.bsfc B10E5

bsfc of blend fuel (gm/kwhr)for B10E5			
Engine Speed (rpm)	time (sec)	mf	bsfc
3253.07	20	0.49	70.41
3903.68	20	0.59	69.45
4554.29	20	0.69	68.95
5204.91	20	0.85	70.65
3650.5	20	1.03	131.91
4056.1	20	1.04	152.38
3034.4		1.05	222.35
2001.4			
2168.2			
2334.9			

Appendix.4.19 Speed vehicle information

Vehicle speed(km/h)	Gear ratio		efficiency	Final gear ratio	Engine speed (rpm)
25	1st	3.901	0.80	4.544	3253.1
30		3.901			3903.7
35		3.901			4554.3
40	2nd	2.432	0.825	4.544	5204.9
45		2.432			3650.5
50	3rd	1.654	0.85	4.544	4056.1
55		1.654			3034.4
60	4th	1	0.87	4.544	2001.4
65		1			2168.2
70		1			2334.9

Appendix 4.20 Cost analysis

No.	Items	Unit	Quantity	Unit price	Total cost
1	Pen (blue and red)	pcs	8	5	40
2	Pencil	Pcs	4	2	8
3	Copy & print	-	4	108	432
4	Note book	pcs	4	15	60
5	CD	Pcs	4	10	40
6	Flash (8GB)	Pc	2	160	320
7	characterization		2	Differed for each	3000
8	Methanol	lit	2.5	216	540
9	ethanol	Lit	2	10	20
10	KOH	gm	500	0.56	280
11	linseed	kg	20	18	360
12	Extraction	kg	20	5	200
13	Transportation				1000
14	others				300
15	**Total**				6600