ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Mechanical, Chemical and Materials Engineering

Exhaust Gas Analysis and Parametric Study of Cotton seed Biodiesel in Diesel Vehicle

Thesis

A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive engineering

By

Marta zeleke

Major Advisor: N.Ramesh Babu (Associate professor)

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MECHANICAL SYSTEMS AND VEHICLE ENGINEERING PROGRAM

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CANDIDATE'S DECLARATION

I declare the work which is presented in the thesis entitled "E*xhaust gas analysis & parametric study of cotton seed biodiesel in diesel vehicle"* in partial fulfillment of the requirements for the award of the degree of master of science in Automotive engineering is an authentic record of my own work carried out from October 2015 to June 2016 under the supervision of N.Ramesh Babu (Asso. Prof), Department of Mechanical and Vehicle Engineering, Adama Science and Technology University.

The matter embodied in this thesis has not been submitted by me 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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This is to certify that the above statement made by the candidates is correct to the best of my knowledge and belief. This project has been submitted for examination with my approval.

N.Ramesh Babu (Ass. Prof)	_______________	_____________
Advisor	**Signature**	**Date**

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Approved by Board of Examiners

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ACRONYMS AND SYMBOLS

ASTM	American society for testing and material
BP	Brake power
BTE	brake thermal efficiency
bsfc	brake specific fuel consumption
B0	pure diesel fuel
B5	5% biodiesel and 95% diesel fuel
B10	10% biodiesel and 90% diesel fuel
B20	20% biodiesel and 80% diesel fuel
B30	30% biodiesel and 70% diesel fuel
B100	pure biodiesel fuel
CN	cetane number
COME	cotton seed oil methyl ester
CIE	compression ignition engine
CO	carbon monoxide
CO_2	corbondioxide
EGR	exhaust gas recirculation
FAME	fatty acid methyl ester
FBP	final boiling point
FFA	free fatty acid
IBP	initial boiling point
Kg	kilogram
Km/hr	kilometer per hour
KN	kilo newton
KOH	potassium hydroxide
KW	kilo watt
LDL	low density lipoprotein
mg	milligram
ml	milliliter
NO_x	oxides of nitrogen
NaOH	sodium hydroxide
P_b	brake power

PM	particulate matter
PP	pour point
SFC	specific fuel consumption
SVO	straight vegetable oil
T_b	brake torque
UV	ultra violet
ULSD	ultra low sulfur diesel fuel
UHC	unburned hydrocarbon

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ABSTRACT

Due to the fast depletion of world petroleum reserves with ever raising demand for diesel in transport, power and agricultural sectors and environmental pollution with increasing exhaust emissions, there is a need for identifying a suitable alternative fuels for use in diesel engines. Currently, alternative fuels are being investigated in detail for application in compression ignition (CI) engines resulting in exciting potential opportunities to increase energy security and reduce gas emissions. Biodiesel is one of the alternative fuels which is renewable and environmentally friendly and can be used in diesel engines with little or no modifications. The present work investigates the impact of biodiesel blend on vehicle performance with four stroke four cylinder diesel engine. Emission test was performed on six cylinder engine vehicle using 100% diesel of petroleum origin (fossil diesel), and B10, B20, B30 of cottonseed oil methyl ester. For the accomplishment of this work an assessment was made by conducting experiments using a chassis dynamometer & exhaust gas analyzer. The vehicle was initially run on diesel to establish their characteristics before running on biodiesel blends. Analysis was carried out on major performance parameters P_b, Tb, bsfc & emissions such as NOx, CO, CO_2, O_2 and HC. It is observed that blends of biodiesel B10, B20 & B30 reduced brake torque by 5%, 7% & 12%, also reduced brake power by 6%, 8% & 11% and increased in fuel consumption by 4%, 8% & 20 % respectively. However, the emissions of the CI engine running on three biodiesel blends were reduced, CO by up to 16%, CO_2 by 17% and HC by 12% & increase NOx by 14% & O_2 by 18% as compared to diesel fuel. The study concluded that cotton seed biodiesel blends containing up to 20% biodiesel can be used in an unmodified diesel engine since their performance and emission characteristics were closer to that of diesel and with reduced toxic gas emissions therefore friendly to the environment.

Key words: Biodiesel, blends, transesterification, performance and emission

1. INTRODUCTION

1.1. Background of the study

Recently, the extinction issue of fossil fuel due to continuous usage become the focus attention in the world who depend on this energy source in every of their activity. The people attention is also increasingly focused on fossil fuel due to the fact that continuous usage of this fuel believed causes environmental problem i.e. air pollution and global warming. Fossil fuels reservoirs around the world are declining due to their non-renewable nature. At the same time the demand for energy is, continuously, increasing to meet the needs of the world population, which is growing significantly. Global warming is being caused by the greenhouse gas emissions. Reducing the dependence on fossil fuels will be beneficial, from environmental point of view, since this will reduce the concentration of carbon dioxide in the atmosphere.

Currently, the world has been tried to look for a solution by exploring and using an alternative fuel which is renewable, environmental friendly, sustainable availability and economically feasible sources of energy have emerged as a priority for research to resolve all these problems [1].

Therefore, explorations to find Biodiesel is the most promising alternative fuel to replace or to reduce dependency on the petroleum-based fuels with multiple environmental advantages and application in compression ignition (CI) engines with no modification. Biodiesel is nonexclusive, biodegradable, non flammable, renewable, nontoxic, environment friendly, and similar to diesel fuel [2].

The main advantages of biodiesel include the following: it can be blended with diesel fuel at any proportion; it can be used in a CI engine with no modification; it does not contain any harmful substances; and it produces less harmful emissions to the environment than diesel fuel. Biodiesel, popularized as the mono alkyl esters which are derived from triglycerides (vegetable oils or animal fats).Transesterification is the most convenient process to convert triglycerides in to biodiesel. Transesterification process involves a reaction of the triglyceride feedstock with light alcohol in the presence of a catalyst to yield a mixture of mono alkyl esters. Currently, using hydroxides of sodium or potassium, is the common route for industrial production of biodiesel [3].

The present study aims to evaluate the potential of biodiesel production from cotton seed oil as a promising feedstock. This study characterizes the properties of cotton seed biodiesel and its 0%, 10%, 20%, 30%, by-volume blends. The properties including kinematic viscosity, density, flash point, cloud point, pour point, acid number, viscosity index, and oxidation stability were assessed. Then, the performance & emission test of the blends of cotton seed biodiesel & pure diesel fuel were performed in a diesel vehicle.

1.2. Statement of the problem

Petroleum- derived fuels are diminishing with their increasing demand every day. Moreover, the combustion products that result from burning of these fuels are considered harmful to the environment & human health. Dependence of the country on importation of oil is leading to the expense of lot of foreign exchange, Ethiopia imports all of its petroleum products and the demand for petroleum fuel are raising rapidly due to the growing economy and infrastructure development. These factors have generated interest in discovering alternative energy sources. So searching for new alternative energy sources that are available, technically feasible, economically viable and environmentally acceptable is necessary.

1.3. Objectives of the study

1.3.1. General objective

The general objective of this study is to evaluate the performance & emission characteristics of a diesel vehicle fuelled with cotton seed oil biodiesel and its blends.

1.3.2. Specific objectives

- To produce biodiesel from cotton seed oil by transesterification process.
- To prepare different diesel-biodiesel blends and characterize for their properties.
- To conduct performance & emission test with pure diesel and diesel-biodiesel blends in CI engine.
- To compare the performance & emission of pure diesel and diesel-biodiesel blends.

1.4. Significance of the study

This experiment helps in understanding how cotton seed oil biodiesel can be used to reduce greenhouse gas emission than pure petroleum fuel and to optimize the performance of diesel engine. Use of the biodiesel in diesel engine has the following significance;

- Reduces the import petroleum fuels.
- Optimize the performance of the engine.
- It helps to protect the environment by lowering the greenhouse gas emissions

1.5. Scope and Limitations of the study

This research work mainly focused on the production of biodiesel from cotton seed, and studying its property to be used as a substitute fuel for petro diesel and testing its emission & performance characteristics on the vehicle and comparing the results with that of petro diesel tested with the same set up. The performance and emission tests were conducted using different experimental setups due to lack of a single set up with all facilities. Due to shortage of budget the complete characterization of biodiesel and its blends was not done. Due to time constraint and budget the test was conducted only with B10, B20 and B30.

2. LITERATURE REVIEW

The world is confronted with the twin crises of fossil fuel depletion and environmental degradation. The indiscriminate extraction and consumption of fossil fuels have led to a reduction in petroleum reserves. Petroleum based fuels are obtained from limited reserves. These finite reserves are highly concentrated in certain region of the world. Therefore, those countries not having these resources are facing a foreign exchange crisis, mainly due to the import of crude petroleum oil. Hence it is necessary to look for alternative fuels, which can be produced from materials available within the country. Although vegetative oils can be fuel for diesel engines, but their high viscosities, low volatilities and poor cold flow properties have led to the investigation of its various derivatives. Among the different possible sources, fatty acid methyl esters, known as Biodiesel fuel derived from triglycerides (vegetable oil and animal fats) by transesterification with methanol, present the promising alternative substitute to diesel fuels and have received the most attention now a day. The Biodiesel can be used in any mixture with petroleum diesel as it has very similar characteristics but it has lower exhaust emissions. Biodiesel has better properties than that of petroleum diesel such as renewable, biodegradable, non-toxic, and essentially free of sulfur and aromatics. Biodiesel fuel has the potential to reduce the level of pollutants, emission properties such as CO, CO_2, UHC and smoke opacity and the level of potential or probable carcinogens [4].

2.1. Source of biodiesel

Biodiesel is defined as: a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats. A “mono-alkyl ester” is the product of the reaction of straight chain alcohol, such as methanol or ethanol, with a fat or oil (triglyceride) to form glycerol (glycerin) and the esters of long chain fatty acids. Biodiesel can be used as B 100 (neat) or in a blend with petroleum diesel. Alternative diesel fuels made from natural, renewable sources such as vegetable oil and fats. The most commonly used oils for the production of Biodiesel are soybean, sunflower, palm rapeseed, canola, cotton seed and Jatropha [5].

2.2. Straight Vegetable Oil (SVO) versus Biodiesel

In spite of the high calorific value, virgin vegetable oils or straight vegetable oil are not considered to be suitable for use in diesel engines. The major problem with the vegetable oils is their inherent high viscosity. Modern diesel engines are sensitive to viscosity changes and high viscosity may lead to poor atomization of the fuel, incomplete combustion, choking of the injectors, ring carbonization and accumulation of the fuel in the lubricating oils. The free fatty acid content of such oils, gum formation due to oxidation and polymerization during storage and combustion, etc. are some of the other common problems which make them unfit for use. Consequently, considerable efforts have been put to develop vegetable oil derivatives that resemble the properties and performance of the hydrocarbon-based diesel fuels. The viscosity of vegetable oils can be reduced by several methods which include blending of oils, micro emulsification, pyrolysis and transesterification [6]. Now a day, improving the clean environment has become a great issue in the world's societies. The pollutants escaped from a transportation sector, such as; from vehicles is the most environmental pollutant and must be under control. Therefore, using cottonseed oil or biodiesel blended fuel can prevent the environment from pollution and the depletion of petroleum fuels simultaneously, also optimizing performance of the engine [7].

2.3. Biodiesel production & process

2.3.1. Conventional production of biodiesel

The most common way to produce biodiesel is by transesterification, which refers to a catalyzed chemical reaction involving vegetable oil and an alcohol to yield fatty acid alkyl esters (i.e. biodiesel) and glycerol. Transesterification reactions are conventionally alkali-catalyzed. Chemical catalysts production many studies of alkali-catalyzed transesterification have been carried out and a reaction temperature near the boiling point of the alcohol (e.g. $60^{o}c$ for methanol) and a 5:1 molar ratio of alcohol to oil were recommended. The presence of water may cause ester saponification under alkaline conditions, and free fatty acids can react with the alkali catalyst to produce soaps [8]. The fatty acid esters are the biodiesel and can be easily separated from the glycerol that is also formed because the biodiesel is less dense and floats on top (similar to oil and vinegar). Breaking the triglyceride molecules apart requires an alcohol (usually methanol) and a catalyst (usually sodium or potassium hydroxide, similar to lye).

The catalyst is used to help speed up the reaction. Several aspects including the type catalyst & other factors that affect the reaction process are reaction time, heat, feedstock, and alcohol/vegetable oil molar ratio, water content and mixing [9].

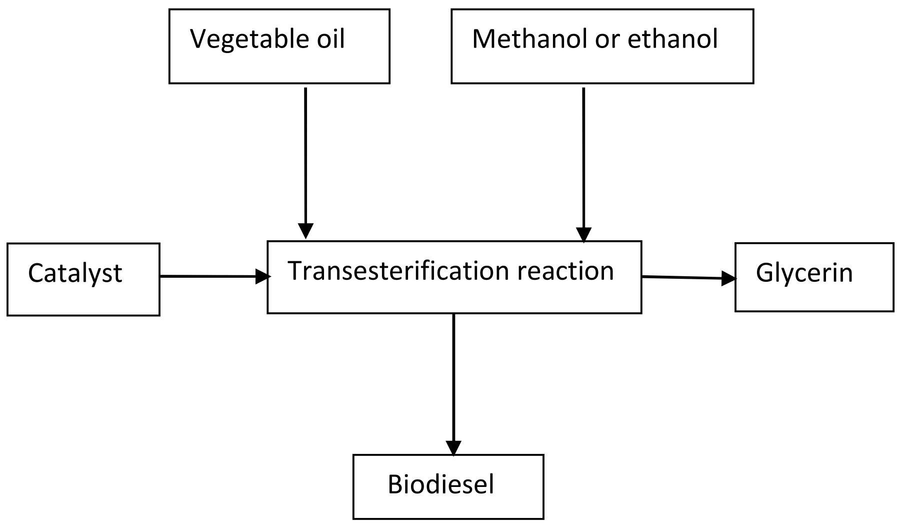


Figure 2.1. Biodiesel production process

2.3.2. Acid-Catalyzed Pretreatment

Special processes are required if the oil or fat contains significant amounts of FFA. Used cooking oils typically contain 2–7% FFA, and animal fats contain 5–30% FFA. Some very low-quality feedstock's, such as trap grease, can approach 100% FFA. When an alkali catalyst is added to these feed stocks, the FFA react with the catalyst to form soap and water as shown in the reaction below:

$$\underset{\text{Fatty acid}}{R-COOH} + \underset{\text{potassium hydroxide}}{KOH} \rightarrow \underset{\text{potassium soap}}{R-COOK} + \underset{\text{water}}{H_2o} \ldots\ldots\ldots\ldots \text{Eq. (2.1)}$$

Up to ~5% FFA, the reaction can still be catalyzed with an alkali catalyst, but additional catalyst must be added to compensate for that lost to soap. The soap created during the reaction is either removed with the glycerol or washed out during the water wash.

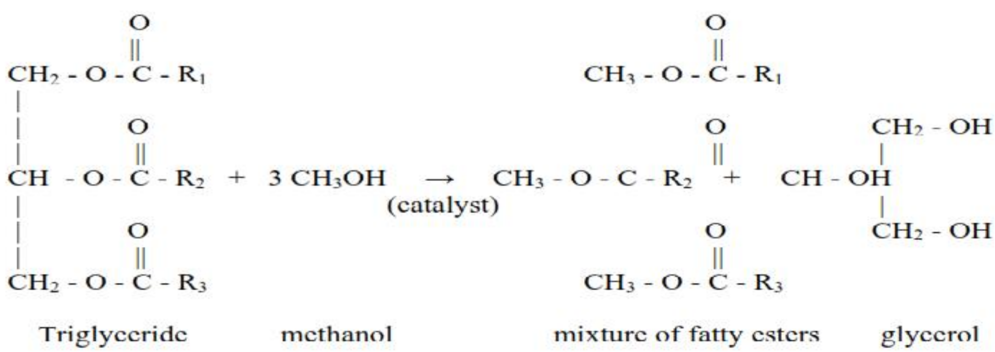
When the FFA level is >5%, the soap inhibits separation of the glycerol from the methyl esters and contributes to emulsion formation during the water wash. For these cases an acid catalyst such as sulfuric acid can be used to esterify the FFA to methyl esters as shown in the following reaction.

$$(\underset{\text{Fatty acid}}{R-COOH} + \underset{\text{methanol}}{CH_3\ OH} \rightarrow \underset{\text{methyl ester}}{R-COOCH_3} + \underset{\text{water}}{H_2\ O}) \ldots\ldots\ldots \text{Eq. (2.2)}$$

This process can be used as a pretreatment to convert the FFA to methyl esters, thereby reducing the FFA level then; the low-FFA pretreated oil can be transesterified with an alkali catalyst to convert the triglycerides to methyl esters. As shown in the reaction, water is formed and, if it accumulates, it can stop the reaction well before completion [10].

2.3.3. Transesterification

Transesterification reactions can be without a catalyst, alkali-catalyzed, acid-catalyzed or enzyme-catalyzed. Alkali-catalyzed transesterification is much faster and most often used commercially (Ma and Hanna, 1999). Alkali-catalyzed transesterification is the most economical process requiring low temperatures and pressures to achieve a 98% conversion yield (Singh et al., 2007). However, one limitation to the alkali-catalyzed process is its sensitivity to the purity of reactants. It is very sensitive to both water and free fatty acids content [11]. The transesterification of the triglycerides in oils with methanol to produce methyl esters of fatty acids (FAME) was found to be the most viable process as the FAMEs have physical and chemical properties which are required for operation of diesel engine and are similar to petroleum based diesel fuel**.**



...Eq (2.3)

Overall Reaction of Triglyceride Transesterification:

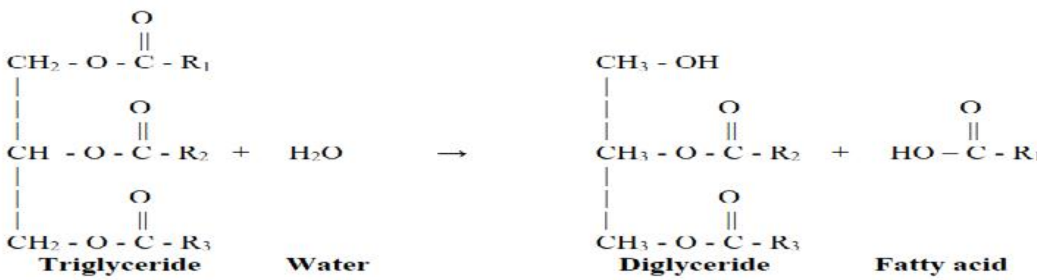
$$(\mathrm{R-COOH} \quad + \quad \mathrm{NaOH} \quad \rightarrow \quad \mathrm{RCOONa} \quad + \quad \mathrm{H_2O}) \ldots\ldots\ldots\ldots\ldots \text{Eq(2.4)}$$

FFA sodium Hydroxide Soap water

Reaction of soap formation (Saponification

This reaction is undesirable because it binds the catalyst into a form that does not contribute to accelerating the reaction. Excessive soap in the products can inhibit later processing of the Biodiesel, including glycerol separation and water washing.

Water in the oil or fat can also be problem. When water is present in the reaction, particularly at high temperatures, it can hydrolyze the triglycerides to di glycerides and form free fatty acid, generally manifests itself through excessive soap production. The soaps of saturated fatty acids tend to solidify at ambient temperatures so a reaction mixture with excessive soap may gel and form a semi-solid mass that is very difficult to recover [12].



Eq. (2.5)

Hydrolysis of triglyceride to form free fatty acid

2.3.4. Washing Biodiesel

The purpose is to wash out the remnants of the catalyst and other impurities. There are three main methods: Water wash only (a misting of water over the fuel, draining water off the bottom), Air bubble wash (slow bubbling of air through the fuel) and Air/water bubble wash (with water in the bottom of the tank, bubbling air through water and then the fuel).Which method works the best is dependent on the quality of the fuel. Washing Biodiesel with water is the oldest and most common method of cleaning biodiesel. Raw unwashed biodiesel is about 3% ethanol. Ethanol is a solvent; it captures soap and other impurities and holds them. Water soaks up that ethanol, releasing impurities to be washed away with water. Water washing is the most flexible way to purify biodiesel. 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 impurities in the water can be drained from the bottom of the container. Several water 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 biodiesel will form soap when mixed with water, and it takes a while for the soap to settle out [13].

2.3.5. Catalysts

Many chemical reactions, including the transesterification reaction that yields biodiesel, require the use of **catalysts.** Catalysts are compounds that are often present in small amounts that cause a reaction to proceed at a faster rate. Often such catalysts can be acids or bases. That means that even when the reaction is over, the reaction solution will still be acidic or basic, depending on the kind of catalyst used (and the other materials present). Then it is usually necessary to **neutralize** the solution, i.e., the solution needs to attain the neutral PH. Not surprisingly, a basic solution can be neutralized with an acid and, vice versa, an acidic solution can be neutralized with a base. When producing biodiesel under basic (more common) or acidic (less common) conditions, neutralization is required. Two of the most commonly used catalysts for transesterification are NaOH and KOH. These Catalysts operate by reacting with the alcohol according to the reaction given below (written using methanol and NaOH but other alcohols and catalysts could be substituted) [14].

$$(CH_3OH + NaOH \rightarrow CH_3O - Na + H_2O) \text{.................................. Eq. (2.6)}$$

2.4. Biodiesel fuel quality

The primary criterion for biodiesel quality is adherence to the appropriate standard. Generally, the fuel quality of biodiesel can be influenced by several factors, including the quality of the feedstock, the fatty acid composition of the parent vegetable oil or animal fat, the production process, the other materials used in this process, and post production parameters. When specifications are met, the biodiesel can be used in most modern engines without modifications while maintaining the engine's durability and reliability.

2.5. Biodiesel fuel properties

The characteristics of Biodiesel are close to diesel fuels, and therefore Biodiesel becomes a strong source to replace the diesel fuels. The conversion of triglycerides into methyl or ethyl esters reduces the molecular weight to one-third that of the triglyceride and also reduces the viscosity by a factor of about eight and increases the volatility marginally. Biodiesel has viscosity close to diesel fuels. These esters contain 10–11% oxygen by weight, which may encourage more combustion than hydrocarbon-based diesel fuels in an engine. The properties of biodiesel can be grouped by multiple criteria.

The most important are those that influence the processes taking place in the engine (ignition qualities, ease of starting, formation and burning of the fuel-air mixture, exhaust gas formation and quality and the heating value, etc.), wear of engine parts (lubricity, cleaning effect, viscosity, compatibility with materials used to manufacture the fuel system, etc.) [15].

Flashpoint

The flash point is defined as the "lowest temperature corrected to a barometric pressure of (760 mm Hg), at which application of an ignition source causes the vapors of a specimen to ignite under specified conditions of test." This test, in part, is a measure of residual alcohol in the B100. The flash point is a determinant for flammability classification of materials. The typical flash point of pure methyl esters is > 200 ° C, while conventional diesel fuel has a flash point of 55-66^{0}c.

Kinematic viscosity@40ºC

Kinematic viscosity: "the resistance to flow of a fluid under gravity". The kinematic viscosity is equal to the (dynamic viscosity/density) the kinematic viscosity is a basic design specification for the fuel injectors used in diesel engines. Too high a viscosity and the injectors do not perform properly. [16].

Distillation (boiling point range)

The distillation (volatility) characteristics of hydrocarbons often have an important effect on their safety and performance, especially in the case of fuels and solvents. Volatility is the major determinant of the tendency of a hydrocarbon to produce potentially explosive vapors. It is also critically important for both automotive and aviation gasoline, affecting starting, warm-up, and tendency to vapor lock at high operating temperature or at high altitude, or both. The presence of high boiling point components in these and other fuels can significantly affect the degree of formation of solid combustion deposits.

Total sulfur

This method covers the determination of total sulfur in liquid hydrocarbons, biodiesel feedstock typically have very little sulfur, but this test is an indicator of contamination of protein material and/or carryover catalyst material or neutralization material from the production process [17].

Cetane number

Cetane number (CN) is a dimensionless indicator that characterizes ignition quality of fuels for compression ignition engines (CIE). Higher cetane numbers indicate reduced ignition delay time, “better” combustion.

• Hexadecane is the high-quality reference compound with assigned CN = 100.

• CN can be correlated to NOx exhaust emissions saturated compounds (higher CN) show reduced NOx exhaust emissions. Since in the CIE burning of the fuel-air mixture is initiated by compression ignition of the fuel, Theoretically, the cetane number is defined in the range of 15-100; the limits are given by the two reference fuels used in the experimental determination, Cetane for diesel engines is analogous to the octane rating in a spark ignition engine, It is a measure of how easily the fuel will ignite in the engine [18].

Carbon residue

“In petroleum products, the part remaining after a sample has been subjected to thermal decomposition...” is the carbon residue. The carbon residue is a measure of how much residual carbon remains after combustion. The test basically involves heating the fuel to a high temperature in the absence of oxygen. Most of the fuel will vaporize and be driven off, but a portion may decompose and pyrolyze to hard carbonaceous deposits.

This is particularly important in diesel engines because of the possibility of carbon residues clogging the fuel injectors. The most common cause of excess carbon residues in B 100 is an excessive level of total glycerin.

Acid number

The acid number is “The quantity of base, expressed as milligrams of potassium hydroxide per gram of sample, required to titrate a sample to a specified end point.” The acid number is a direct measure of free fatty acids in B100.

The free fatty acids can lead to corrosion and may be a symptom of water in the fuel. Usually, for a base catalyzed process, the acid value after production will be low since the base catalyst will strip the available free fatty acids. However, the acid value may increase with time as the fuel degrades due to contact with air or water.

Free glycerin

Free glycerol is the glycerol present as molecular glycerol in the fuel. Free glycerol results from Incomplete separation of the ester and glycerol products after the transesterification reaction. This can be a result of imperfect water washing or other approaches that do not effectively separate the glycerol from the biodiesel. The free glycerol can be a source of carbon deposits in the engine because of incomplete combustion [19].

Density of biodiesel

Fuel density is the mass per unit volume, measured in a vacuum. Since density is strongly influenced by temperature, the quality standards state the determination of density at 15 °C. Fuel density directly affects fuel performance, as some of the engine properties, such as cetane number, heating value and viscosity are strongly connected to density. The density of the fuel also affects the quality of atomization and combustion. As diesel engine fuel systems (the pump and the injectors) meter the fuel by volume.

Cloud point

The cloud point is “The temperature at which a cloud of wax crystals first appears in a liquid when it is cooled down under conditions prescribed in this test method.” The cloud point is a critical factor in cold weather performance for all diesel fuels. The cloud point, however, is another parameter that can be predicted ± 5 % with knowledge of the esters composition, but producers are advised to be equipped to perform this test. Since the saturated methyl esters are the first to precipitate, the amounts of these esters, methyl palmitate and methyl stearate, are the determining factors for the cloud point [20].

Pour point (PP)

The pour point is the temperature at which the fuel contains so many agglomerated crystals that it is essentially a gel and will no longer flow. This occurs if the temperature of the biodiesel drops, when the micro crystal merges and form large clusters, which may disrupt the flow of the biodiesel through the pipes of the engine’s fuel system. Similarly to the cloud point, the pour point values also depend on the feedstock the biodiesel was produced from [21].

Biodiesel lubricity

Lubricity describes the ability of the fuel to reduce the friction between surfaces that are under load. This ability reduces the damage that can be caused by friction in fuel pumps and injectors (Schumacher, 2005). Lubricity is an important consideration when using low and ultra-low sulfur fuels (ULSD). The lubricity of biodiesel is excellent. Biodiesel may be used as a lubricity improver. The lubricity of biodiesel depends on the feedstock it is produced from. Biodiesel from Jatropha oil has the highest and biodiesel sunflower oil has the lowest lubricity.

Generally, it can be stated that 1% (v/v) biodiesel mixed with ultra-low sulfur diesel fuel (ULSD) already provides lubricity that meets the requirements of the commercial diesel fuel's lubricity quality standards [22].

Table.2.1. properties of diesel fuel & cotton seed oil

s.no	property	diesel	Cotton seed
1	Calorific value	43,000	39,648KJ/Kg
2	Flash point	44 ^{o}c	234 ^{o}c
3	Fire point	49 ^{o}c	192 ^{o}c
4	viscosity	0.278poise	2.52poise
5	density	835 Kg/m^3	850 Kg/m^3

Table 2.2. ASTM D6751biodiesel (B100) specifications [44]. Source:American society for testing & materials standard specification for biodiesel fuel (B100)Designation D6751-07(2007)

property	ASTM Method	Limits	units
Flash point	D93	130min	^{o}c
Water & sediment	D1796	0.05max	%volume
Carbonresidue,100%sample	D4530	0.05max	%mass
Kinematic viscosity, 40^{o}c	D445	1.9-6.0	mm^2/sec
Cetane number	D613	41-55	^{o}c
Cloud point	D2500	As reported	^{o}c
Acid number	D974	0.50max	Mg KOH/g

2.6. Need of blending and its effect on performance

Engelmann et al. [23], reported that 10–50% soybean oil fuel blends with diesel minimize the carbon deposition in combustion chamber. Quick [24] used over 30 different vegetable oils to operate compression engines and reported that the use of raw vegetable oil fuels can lead to premature engine failure. Blending vegetable oils with diesel fuel was found to be a method to reduce chocking and extend engine life. The similar results were reported by Bartholomew [25], Barsic and Humke [26], working on different oils such as pea nut oil, cottonseed oil, sun flower oil, rapeseed oil, and sun flower oil respectively.

2.7. Oil extraction technique

There are two main types of processes for obtaining oil: physical and chemical. The physical process, or extraction, involves the use of mechanical power to remove oil from the seed, such as batch hydraulic pressing and continuous mechanical pressing (screw presses). Chemical processes, or extraction, are based in solvent extraction. The commercial methods for the extraction of vegetable oils are reviewed, including: batch hydraulic pressing, solvent extraction and continuous mechanical pressing (also known as screw press).

2.7.1. 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. Work with this type of equipment was considered labor intensive. With the emergence of the continuous screw- press, the only application that still requires the hydraulic press is the one that requires gentle handling.

2.7.2. 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 cited.

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. Such as screw press, in order to optimize this simple process so it can produce more oil, with high quality at a lower cost [27].

2.7.3. 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).

The most commonly used solvents were light paraffinic petroleum fractions, such as the hexanes, heptane and pentanes. The hexane oilseeds oil Presses was finally chosen because of its ease to evaporate and left no residual obnoxious odors or tastes. Low moisture content of the oil is advantageous in terms of storage stability since the lower the moisture content, the better the storability and suitability to be preserved for a longer period [28].

2.8. Cotton production

Cotton is a warm-weather shrub or tree of the Malvaceae family; it's an important fiber crop of global significance and is grown in tropical and subtropical Regions of more than eighty countries. Cotton is primarily cultivated for its lint or fiber, In other words, lint is the main products of cotton crop. Cottonseed oil is a popular vegetable oil, which is extracted from, as the name suggests, cottonseed this oil is mainly extracted from two species of cotton - Gossypium hirsutum and Gossypium herbaceum. This oil is inexpensive and has a longer shelf life than most cooking oils. It is used as a salad oil, in mayonnaise, and salad dressings. There are also certain ill effects of using this cooking oil [29].

a) Opened ball exposed lint b) unopened ball c) cotton seed d) cotton plant

Figure 2.2. Cotton production

2.8.1. Cotton production in Ethiopia

In Ethiopia, a good cotton yield is obtainable from areas varying in altitude from sea level to about 1000m.A large area of the country particularly the country's potential cotton growing areas such as Omo-Ghibe,Wabi Shebelle, Awash, , Blue Nile, and Tekezze river basins lie within this altitude range .Cotton has grown in many of regions in the country. In each region there are wide potential areas in Tigray, in Amhara, in SNNPR, in Oromia, Gambella, Benshangul, Afar and Somali [30].

2.9. Composition of cotton seed oil

Its fatty acid profile generally consists of 70% unsaturated fatty acids (18% monounsaturated, and 52% polyunsaturated), 26% saturated fatty acids. The contents of cottonseed oil are as follow. Linoleic acid: 49 % to 58 %, Oleic acid: 15 % to 20 %, Palmitic acid: 22 % to 26 %, Behenic acid and lignoceric acid/Arachidic acid: 10%.

2.10. Engine performance & emission with cotton seed oil

Studies and researches were carried out on the properties, emission & performance of biodiesel in diesel engine. Tanzer Eryilmaz et al. [31] performed test on fuel properties of cottonseed oil methyl ester and its blends with diesel fuel, such as density, kinematic viscosity, calorific value, flash point and water content. The density of biodiesel and diesel fuels decreases linearly with increasing temperature. The density value of pure biodiesel was found higher than diesel fuel.

The kinematic viscosity of biodiesel and diesel fuels decreases exponentially with increasing temperature. The kinematic viscosity of blend fuels increases with increase the pure biodiesel blend ratio. The calorific value of fuels decreases linearly with blend ratio. The calorific value of the B100 was found lower than diesel fuel.

Sathiyagnanam et al, [32] described that on different blends of 25%, 50% & 75%, cottonseed biodiesel the performance & emission of CI engine have been measured. Therefore, significant engine performance parameters such as specific fuel consumption (SFC), and brake thermal efficiency (BTE) for biodiesel and its blends were calculated, The SFC increases with increase in percentage of biodiesel in the blends due to the lower heating value of biodiesel. The CO emissions of biodiesel and its blends are evidently lower than those of diesel fuel, at full load, diesel had the highest HC emission.

The oxygen content in the biodiesel results in better combustion and increases the combustion chamber temperature, which leads to higher NOx emissions, especially at high engine loads.

Siva Kumar et al. [33] performed performance & emission test on a single cylinder four stroke engine, various blends of biodiesel such as B0, B5, B10 were used. Thermal efficiency with biodiesel mixtures was slight lower than that of neat diesel fuel due to lower heating value of the mixtures. Biodiesel mixtures showed less CO, PM, smoke emission than those of neat diesel fuel.

The advantages of bio-diesels as diesel fuel are the minimal sulfur and aromatic content, and higher flash point, lubricity, cetane number, biodegradability and no toxicity. On the other hand, their disadvantages include the higher viscosity and pour point, and the lower calorific value and volatility. Furthermore, their oxidation stability is lower, there are hygroscopic, and as solvents may cause corrosion in various engine components.

As my understanding from the review of the literatures, that biodiesel blended fuels can effectively reduce the environmental pollution without any major modification to the design of the engine. Therefore, in this study the cotton seed biodiesel is used in diesel engine as a fuel. Finally, the intention in the thesis work is testing the performance & emission of cotton seed biodiesel in diesel engine to improve the engine performance and reduce pollution as environmental benefit.

2.11. Dangers of cotton seed oil as a cooking oil

Even though cottonseed oil is alternative for cooking, as this oil does not turn rancid due to its long shelf life, it also has some drawbacks. It is mildly inflammatory in nature and also has some components which may prove harmful to health.

Natural Toxin

According to many nutritionists, cottonseed contains some natural toxins. One such naturally occurring toxin present in the cottonseed is gossypol. This toxin is produced in the seeds and helps the plant against the infestation of insects. Gossypol tends to decrease the motility of the sperms and interferes with spermatogenesis. This condition can prove detrimental to men's fertility. The presence of gossypol in the body tends to interfere with the metabolism of potassium and can be a causative factor for paralysis among men who have a low intake of potassium in their diet.

Generally, most commercial manufacturers of this oil, process it in such a way that the gossypol content is removed from the final product. However, a risk remains.

Fat profile

Another danger is that it has a high content of saturated fats. Cottonseed oil also contains very low levels of monounsaturated fats and heart-healthy omega 3 fatty acids. These saturated fats tend to increase the levels of low density lipoproteins (LDL) or bad cholesterol in the body.

Continuous use can lead to many cardiovascular diseases such as blockage of arteries (atherosclerosis), heart attacks, angina, and the like. Cottonseed also contains more than fifty percent of omega-6 fatty acids which may lead to the deficiency of omega-3 essential fatty acids. The oil undergoes the process of hydrogenation which creates Trans fats, which can raise the levels of serum cholesterol [34].

Allergic Reactions

Since, there is a similarity in the molecular structures of the composition of cottonseed and peanut oil, people who are allergic to gluten or peanuts also suffer from the same allergic reactions after consuming cottonseed oil. Rashes, itching or burning sensation, and swelling can be triggered due to an allergy. In extreme cases, the individual may experience breathlessness, scratchy throat, and heaviness in the chest.

Pesticides

since cotton is not a food crop, many harmful pesticides are sprayed to protect the crop. These pesticides are composed of harmful toxins including cyanide, propargite, dicofol, trifluralin, and naled which are carcinogenic in nature. These pesticides seep into the cotton seeds and when oil is extracted from these seeds some amount of toxins gets mixed. Using such oil for consumption can trigger the development of cancerous cells and make an individual more prone to different types of cancer [35]. It's important to note that not all plant oils are bad. For example, coconut oil and olive oil are both excellent.

- MOST HEALTHY oil are Grape seed, Walnut & Avocado Oil
- LEAST HEALTHY oil are Palm oil & Cottonseed oil [36]

3. MATERIALS AND METHODS

This research was done mainly based on experimental activities.

The methods & procedures used in the thesis work were the following:-

1. Sample collection.
2. Extraction of oil by mechanical pressing.
3. Transesterification reaction.
4. Characterization of pure biodiesel & blends of biodiesel using different parameters.
5. Preparation of blends of fuel, performance & emission test set up.
6. Perform the performance & emission test of pure diesel fuel & blend of biodiesel in a vehicle.
7. Comparing the test result from pure diesel & diesel biodiesel blend according to performance & emission parameters.

Crude cotton seed oil was extracted from expeller, Addis Modjo Edible Oil Complex Company (i.e. screw pressed cottonseed oil) by mechanical pressing. Methanol, potassium hydroxide were obtained from an agent of Yeshadam Chemicals Trading PLC in Addis Ababa, Transesterification and blending process was done in Chemistry department of ASTU. Performance & emission test was conducted in automotive work shop of ASTU & Maj,General Mulugeta Buli technical college. Conventional diesel fuel purchased from outlets nearby.

3.1. MATERIALS

Table 3.1 & table 3.2. Gives the list of materials and equipment's used in biodiesel production

Table 3.1. Materials used for biodiesel production

S. No	List of materials
1	Methanol
2	Potassium hydroxide
3	Cotton seed
4	Crude Cotton seed oil
5	Distilled water

Table3.2. Equipment's used for biodiesel production

S.no	List of equipment's
1	Separator funnel
2	Magnetic stirrer with hot plate
3	Digital weighing scale
4	Glass ware, beaker
5	Thermometer
6	Stand for separator funnel
7	Conical flask

3.2 METHODOLOGY

3.2.1. Production of cotton seed oil

The raw cotton was collected from cotton ginning factory and separated the seed from the lint before the oil extracted from the seed. The lint goes to textile industry & the seed for oil extraction to oil producing factory.

There are five core steps in production of crude oil from cotton seed in large scale in Addis-modjo edible oil complex share company.

- Cleaning the seed
- De hulling & separation of hulls (husk)
- Heat treatment or cooking
- Mechanical pressing
- Filtering

Oil seed cleaning

The raw material cotton seed was conveyed to pre cleaner to remove foreign matters, stones, dust & impurities, & also the oil seed passed through a magnetic separator to trap metallic impurities.

De hulling and separation of (hulls) husk the cleaned cotton seed was conveyed & elevated to decorticator for break down the seed structure and rapture the oil cells. The husk is then separated using sucking air from cyclone.

Heat treatment or cooking /conditioning/ oil seed

The flaked or decorticated oil seed elevated to the cooker mounted over the mechanical press, the cooking was carried out at a temperature of 80-110 ^{o}c by steam. Its purpose is to adjust natural moisture content of the seed (3-6%), coagulate protein & makes the seed permeable to the flow of oil, reduce viscosity of oil & sterilize the seed, destroy enzymatic action to prevent growth of mould and bacteria. The time taken for cooking was 90 minutes.

Mechanical pressing

Conveyed the cooked oil seed for screw pressing, screening & pumping, the crude oil was extracted & cake part separated, finally, the extracted crude cotton seed oil was filtered from impurities.

3.2.2. Determination of crude oil content

The amount of processed cotton seed for oil extraction was 40 kg which were crushed/ broken into small pieces and pressed mechanically in the machine, by the first outlet found the crude oil by other out let the cake or residue, finally 7 liter crude cotton seed oil was extracted. After the crude oil was collected from the factory, transesterification process was takes place in Adama science & Technology University, chemistry department laboratory.

3.2.3. Transesterification of cotton seed oil

Transesterification of cottonseed oil involves making triglycerides of cottonseed oil to react with methyl alcohol (methanol) in the presence of a catalyst (KOH) to produce glycerol and fatty acid ester. Therefore, for this process 5 gram of potassium hydroxide was dissolved in 100 ml of methanol. The mixing ratio was taken as (the catalyst and alcohol quantity are 1 % and 20 % of oil respectively). Which is fully dissolved for each sample of 500 ml of crude cotton seed oil.

The transesterification process of producing cottonseed biodiesel.

1. Crude cotton seed oil (500ml) was measured & poured in a flask per each sample.

Figure3.1. measuring the crude oil sample

2. 100 ml of Methanol and 5 gm KOH were measured and taken into a flask for each sample.

Figure3.2. Measuring KOH & dissolve it in methanol

3. Stir or shake the mixture until the KOH is fully dissolved in methanol.
4. Heat the crude cotton seed oil to 65^0 C.

Figure3.3. Heating the crude oil

5. Add the dissolved mixture (KOH & Methanol) in to the heated oil.
6. Heat the dissolved mixture for 1hr at fixed temp of 65°C, heating & stirring takes place at the same time continuously, and measure the temperature of the reactant for every 10 minutes with the help of thermometer (the boiling point of methanol is 60°C). After one hour, switch off the heating mantel to stop the reaction process.

Figure3.4. Heating the mixture of (KOH & methanol) with crude oil.

7. When the reaction time reaches around 45 minutes glycerin starts to separate and settle at the bottom, a clear solution appears at the bottom.

Biodiesel Separation and Purification

8. On completion of the transesterification process, the products were poured into a separating funnel for 24 hours. Two phases (having different density) were formed.

Figure 3.5. Two layers of oil formed

The upper layer consisted of the biodiesel, alcohol and some soap, which may have been formed as a result of side reaction and the lower layer consisted of glycerin, excess alcohol, catalyst impurities, and traces of unreacted oil. The lower layer was drained. The glycerin can be used to make soap.

Figure 3.6. Upper layer (biodiesel)

Figure 3.7.lower layer (glycerin & fatty acid)

9. To remove the alcohol and catalyst present in the ester (biodiesel), the ester was washed with warm distilled water at 55°C.

Washing of the biodiesel was performed under the following procedures;

- Distilled water was heated at 55°C.
- The biodiesel was poured in a separator funnel.
- The water was sprayed to the oil slowly.
- The oil & water was shacked for 4 minutes.
- The oil was left for 24 hrs. Hanging in a separator funnel.
- The water and soap settled at the bottom and separated by opening the valve of the funnel.

10. Repeat washing process six times until water is mostly clears.

Figure 3.8. 1st & 2nd step of washing of biodiesel with distilled water (soap formation)

Figure 3.9. Soap & impurities during washing process

Figure 3.10. Final washing step, water becomes clear

Figure 3.11. Biodiesel after washing process

11. The final washed product (biodiesel) was kept in hot plate set at a temperature of 100^0 C for 1 hr to remove traces of alcohol and water in the biodiesel.

Figure 3.12. Heating & drying the biodiesel

Following the procedures mentioned above, all the other biodiesel fuels were produced.

Fig 3.13. Finally collected biodiesel

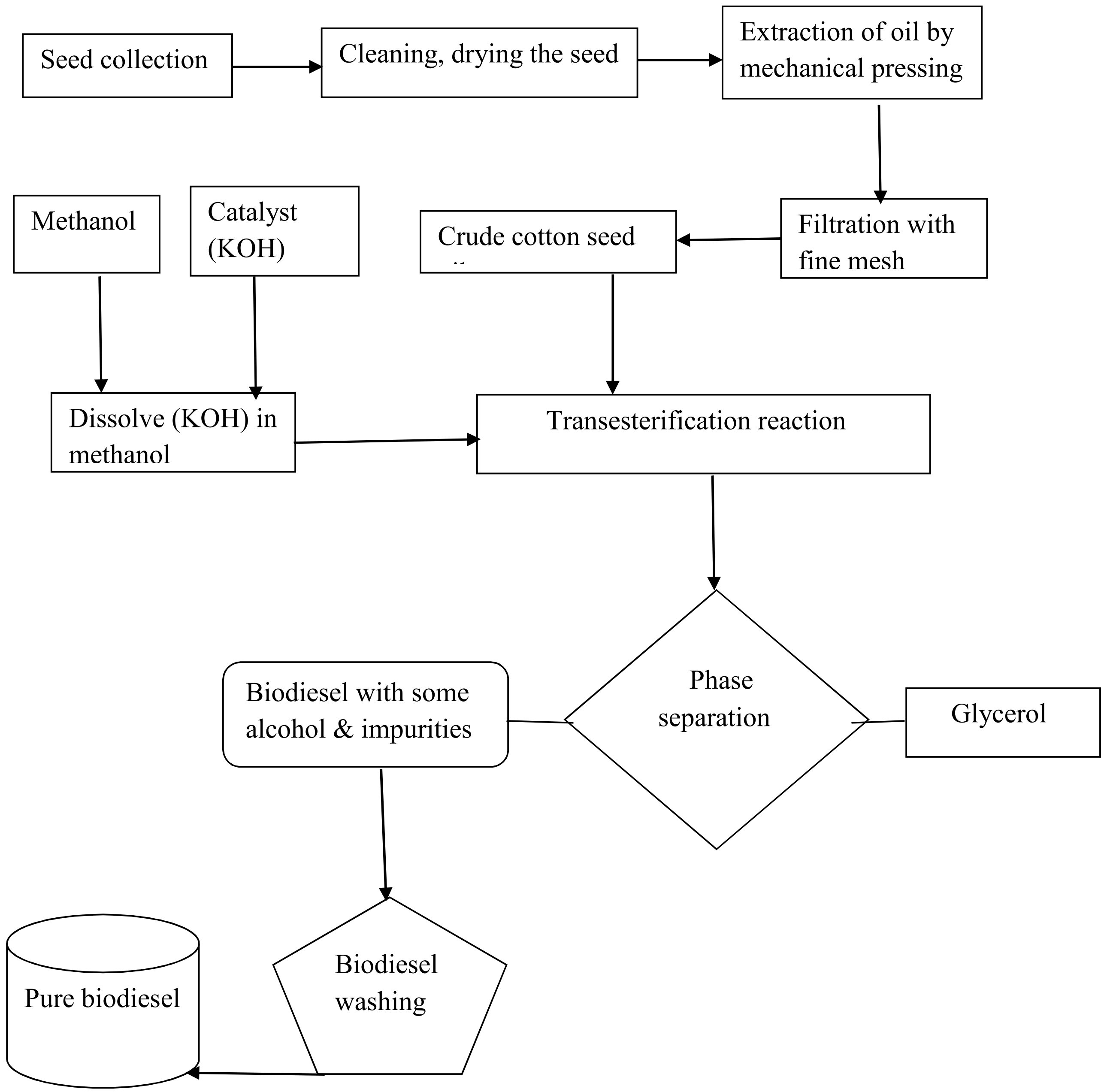


Figure 3.14. Layout for the production of biodiesel

3.2.4. Characterization of cotton seed biodiesel

Characterization is the process of determining physicochemical properties of petroleum products and non-petroleum products like biodiesel blends. Before testing the performance & emission of blend fuels it's very important to check physicochemical properties. The properties of the fuel include kinematic viscosity, flash point, cloud point, acid number, density, distillation range.

Fuel blends prepared for characterization are B10, B20, B30 and B100. To prepare B10 blend fuel, 50ml of cotton seed biodiesel mixed with 450ml of diesel fuel were measured with 500ml beaker & stirred, to produce B20, 100ml of biodiesel & 400ml diesel fuel mixed & for B30 150ml of biodiesel blend with 350 ml of diesel fuel. Properties of biodiesel was measured in ASTU, (UV spectroscopy & PH) in chemistry department) & other physical properties mentioned below are performed in Ethiopian Petroleum Supply Enterprise (quality control laboratory).

a) Pure diesel b) biodiesel c) B10 d) B20 e) B30

Figure. 3.15. Blends of biodiesel for characterization

3.2.4.1. Determination of density (ASTM D4052)

Density is a fundamental physical property that can be used in conjunction with other properties to characterize both the light and heavy fractions of petroleum products .Determination of the density or relative density of petroleum and its products is necessary for the conversion of measured volumes to volumes at the standard temperature of 15°C. *Digital Density Analyzer*: - a digital analyzer consisting of a U-shaped, oscillating sample tube and a system for electronic excitation, frequency counting, and display. The analyzer shall accommodate the accurate measurement of the sample temperature during measurement. Introduce a small amount (about 1 to 2 ml) of sample into the clean, dry sample tube of the instrument using a suitable syringe.

Ensure that the sample tube is properly filled and that no gas bubbles are present. The sample must be homogeneous and free of even the smallest gas bubbles. Check the integrity of the filled sample by using optical or physical methods to verify absence of gas bubbles. If gas bubbles are detected, empty and refill the sample tube, and recheck for gas bubbles. After the instrument displays a steady reading to four significant figures for density, relative density, or API Gravity, indicating that temperature equilibrium has been reached, record the density, relative density, API Gravity or both, as appropriate .If the two determinations do not differ by more than 0.0002 g/mL for density or 0.0002 for relative density, average the two determinations, otherwise, discard both determinations and repeat the analysis using two new test specimens until the acceptance criteria identified above is satisfied. In reporting density, state the test temperature and the units (for example: density at 20°C = 0.8765 g/mL or 876.5 kg/m^3). Report the final result for density or relative density to four significant figures [37].

Figure 3.16. Digital density analyzer

3.2.4.2. Determination of boiling point range (ASTM D86).

The standard procedure for measuring the boiling point procedure for diesel fuel & biodiesel is the distillation test. The simple distillation apparatus was used for the test. Distillation process was conducted on a sample of fuel & boiling point data were recorded using thermometer, the data include the boiling temperature corresponding to initial boiling point (IBP), 10%, 40%, 50%, 90% increment of the volume of distilled fuel &final boiling point (FBP). Each recorded temperature were corrected to 760 mmHg pressure by applying the correction factor-relation (ASTM 2002 D1250-80, 1980).

$C_c = 0.00012\ (760 - P)\ (273 + t_c)$……………………………………………..Eq.3.1

Where, t_c = the observed temperature reading, ^0c

Cc= correction to be added algebraically to the observed temperature readings.

P= barometric pressure, prevailing at the time and location of the test, mmHg

Hence corrected temperature (^0c) = $t_c + c_c$………………………………………..Eq.3.2

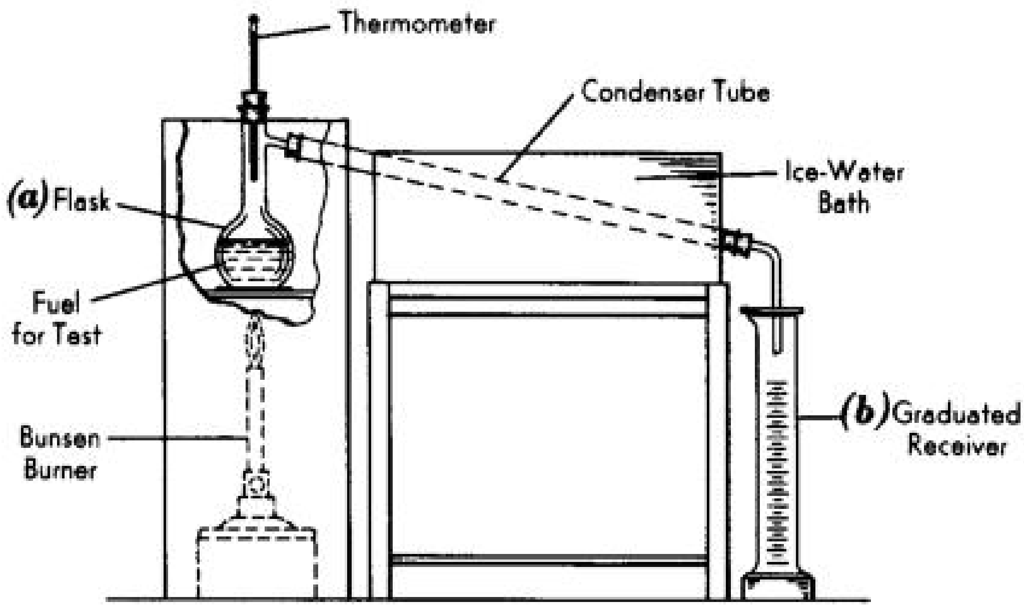


Figure3.17. Distillation apparatus & its sectional view.

3.2.4.3. Determination of flash point (FP) (ASTM D93).

The flash point were measured with standard test method Pensky - martens closed cup tester using ASTM D93, the apparatus and method consist of the controlled heating of the biodiesel sample in a closed cup introducing an ignition source, and observing if the heated biodiesel flashes. The temperature at which the biodiesel flashes is recorded as the flash point [38].

Correction of flash point: taken the ambient barometric pressure

Corrected flash point (CFP) = T + 0.25 (101.3 – K)

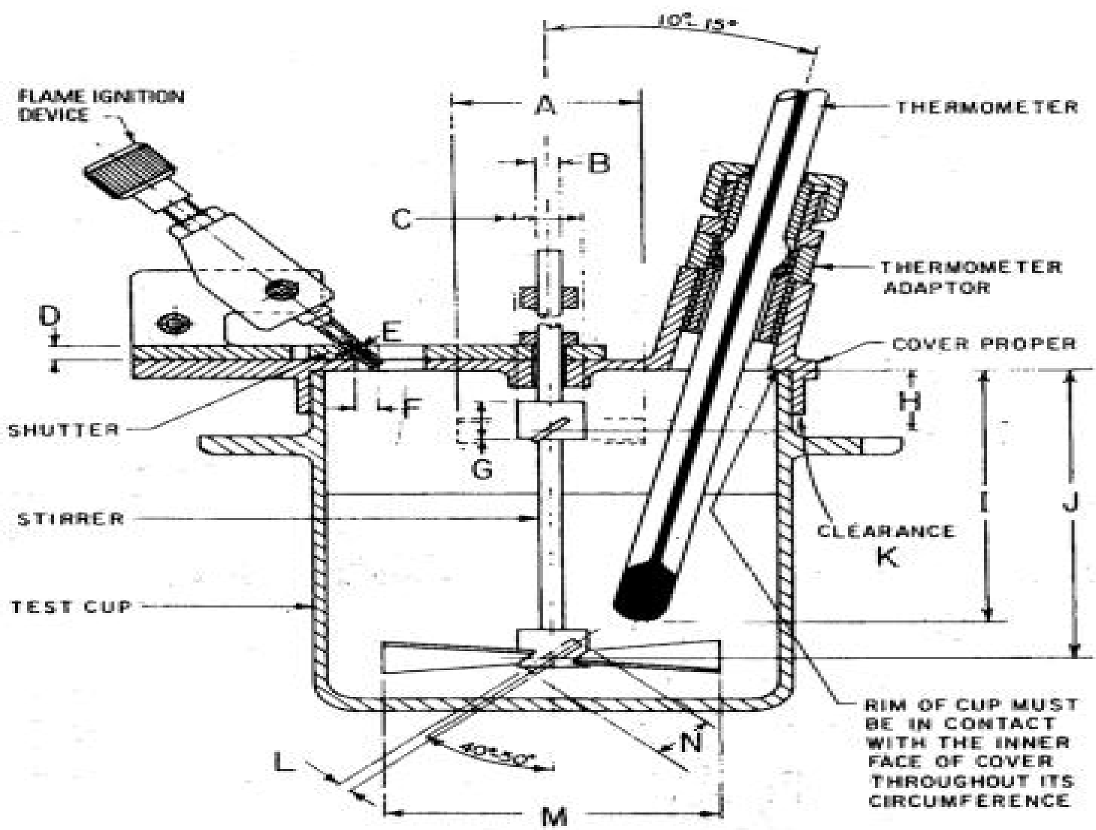
Corrected flash point (CFP) = T + 0.033 (760-P)

Corrected flash point (CFP) = F + 0.06 (760-P)……………………………….…..Eq.3.3

Where, T = observed flash point temperature (^{0}c), K = ambient barometric pressure (K pa),

P = ambient pressure (mmHg), F = observed flash point (^{0}F)

Figure 3.18. Pensky-martens cup tester



Pensky –martens cup sectional view

3.2.4.4. Determination of cloud point (CP) (ASTM D 2500).

The cloud point of petroleum product is an index of the lowest temperature of its utility of certain applications. Mixtures commonly used for temperature reduction are the following:-

1. Ice and water up to 10^{o}c,
2. Crushed ice and sodium chloride crystals, up to -12 ^{o}c.
3. Crushed ice and calcium chloride crystals up to -26 ^{o}c

The cloud point was determined by visually inspection for a haze in the normally clear fuel, while the fuel was cooled under carefully controlled conditions. The sample was continuously monitored and the temperature (^{o}c) that corresponds to the formation of first cloud in the fuel was recorded.

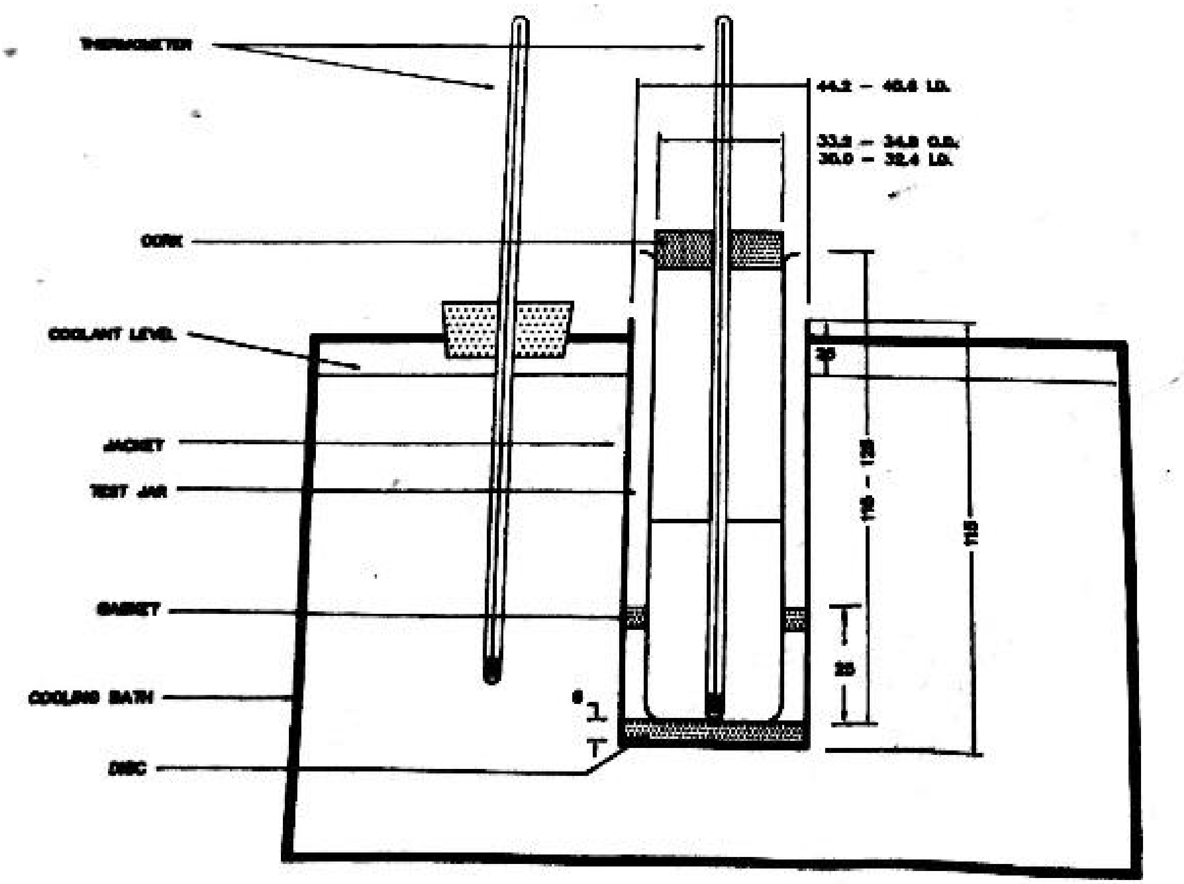


Figure3.19. cloud point apparatus & its sectional view

3.2.4.5. Determination of kinematic viscosity (ASTM D445)

Kinematic viscosity of biodiesel was determined using ASTM D445, standard test method for kinematic viscosity of transparent and opaque liquids. Cannon-fenske glass capillary viscometer tube was used in a SETA KV-8 viscometer bath. The liquid in bath heated to 40^{o}c, sample fuel is filled in the capillary viscometer tube & inserted in the bath and kept for 30 minutes to maintain an equilibrium of bath temperature. The time (t) is recorded for a fixed volume of liquid to flow under gravity through the capillary of a calibrated viscometer. Kinematic viscosity is then calculated as the product time (t) in second and the calibration constant (K) of the viscometer tube [39].

Kinematic viscosity = K* t……………………………………………….……..Eq.3.4.

Where, K = calibration constant for viscometer in (mm^2/sec)

t = time in second

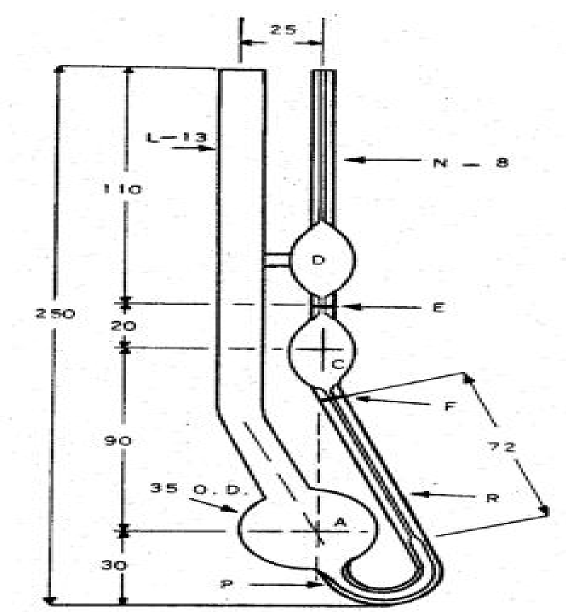


Figure.3.20. Kinematic viscosity apparatus & cannon fenske capillary viscometer tube

3.2.4.6. Determination of acid number (ASTM D974*)*

Standard alcoholic KOH solution (0.1M) was prepared by dissolving 6g of KOH (pellet) to one liter of anhydrous isopropyl alcohol (anhydrous <0.9% water) in a 2L flask & boiled for 15 minute, while stirring.

Two grams of $Ba(OH)_2$ was added & again boiled for 10 min, cooled to room temperature stood for 2hrs and filtered. The indicator p-Naphtholbenzein was used. One gram of sample oil was added into an appropriate size Erlenmeyer flask; 100ml of titration solvent (isopropyl alcohol) and 0.5 ml of the indicator solution was added & stirred until sample is completely dissolved in the solvent to form yellow orange color. The solution is then titrated below a temperature of 30^0c by adding 0.1M KOH solution with consistent shaking till the orange color change in to green or green brown at the end point.

Titration Solution: - Add 500ml of toluene (**warning-** its flammable Vapor & harmful. Keep away from heat, spark and open flame.) And 5ml of distilled water to 495ml of anhydrous Isopropyl alcohol. Blank titration was performed on 100ml of the titration solvent and 0.5ml of the indicator solution, adding 0.1ml increments of the 0.1M KOH solution. The KOH solution was standardized frequently to detect molarity change of 0.0005 [40].

The volume of 0.1M KOH (V_A) for the sample titration, and volume for the blank (V_B) were noted. Then; the total acidity (acid number (mg KOH/g)) was calculated using

$$AN = \frac{(VA - VB) * N * 56.1}{Wo} \quad \text{……………………………………………………..…Eq. (3.5)}$$

Where W_0= sample weight (gm).

V_A=volume of KOH used for the sample (ml).

V_B=volume of KOH used for the blank (ml).

N= concentration of KOH used (Molar)

3.2.4.7. Determination of cetane index (ASTM D976)

Cetane Index – (ASTM D976 or D4737) the cetane index is a calculated quantity that is intended to approximate the cetane number where a test engine is not available for determining this property. It is much cheaper to determine than the engine-based cetane number but its accuracy is limited to the type of fuel on which the equation is based.

It generally does not provide an accurate indication of cetane number if the fuel contains cetane improving additives or for non-petroleum-based alternative fuels. Two ASTM methods are available for computing the cetane index [41].

ASTM standard D 976 gives the following empirical equation for the cetane index:

$$\text{Cetane Index} = 454.74 - 1641.416\,D + 774.74\,D^2 - 0.554\,B + 97.803[\text{Log } B]$$

Where D = fuel density at 15°c in g/ml.   B = corrected mid boiling point °c

3.2.4.8. Determination of PH of biodiesel

Biodiesel pH should be neutral (pH 7), or vary between 6 and 8, it should be noted that according Kac [25], PH of commercial diesel and was taking as reference, the value obtained Was 6.02, this indicated that pH values of biodiesel obtained are close to the pH of commercial diesel. PH meter was used brand Hanna Instruments, Model HI 9813-6, with a resolution and accuracy of 0.1 (20°C) ± 0.2. The pH meter was calibrated by buffer solution before making test. Once calibrated pH meter was poured 50 ml of biodiesel sample was introduced electrode, and measurements were performed for 5 min until the readings stabilized [42].

Figure.3.21. PH measuring instrument

3.2.4.9. Determination of UV spectrum

The study of the interaction between matter and radiation is known as spectroscopy and it is seen as a suitable and precise analytical method in quality control analysis. It measures radiation intensity as a function of wavelength. Ultraviolet – Visible (UV) spectroscopic analysis is fast becoming a common technique for providing analytical data on degradation of biodiesel.

This absorption spectroscopy uses electromagnetic radiations between 190 nm to 800 nm and is divided into the ultraviolet (UV, 190-400 nm) and visible (visible, 400-800 nm) regions.

Oxidative stability is of concern, especially when storing biodiesel over an extended period of time Biodiesel oxidation follows a free radical mechanism that starts with the absorption of a hydrogen atom. Using quartz cuvette the baseline was carried out by pure methanol solvent. The samples were dissolved in methanol and small volume of it was taken by capillary tube and transferred to quartz cuvette half filled with methanol. Then, scanning was done on the selected wave length range. From the spectral data obtained, the type of absorption was determined.

Figure.3.22. UV measuring apparatus

3.2.5. Blending of cotton seed biodiesel with diesel fuel

To test on the vehicle, blend fuel were prepared per each sample test B10, B20, B30, and stirred thoroughly. The mixture was allowed to settle for about 4 -6 hrs. For miscibility or phase separation and consistency. In this study the method used to blend the cottonseed biodiesel with conventional diesel fuel is splash mixing type rather than inline mixing type because, bio-diesel is slightly heavier than conventional diesel fuel (specific gravity 0.86 compared to 0.84 for 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 diesel is added at top of biodiesel fuel, it will not mix.

Figure3.23 From left to right B100, B10, B20, B30 blend of biodiesel ready for performance test

Figure 3.24. From left to right B10, B20, B30 blends of fuel for emission test

3.2.6. Experimental Facilities for the Test

The experimental set up used in this investigation is shown below, The measurements of gaseous emissions were carried out on Maj. General Mulugeta buli technical college using a FGA- 4100 emission analyzer & on the Mercedes Benz truck vehicle at selected five engine speed (500, 1000, 1500, 2000, 2500 rpm) & the performance measurement were carried out in the department of mechanical & vehicle engineering work shop of Adama science & technology university.

The test was performed on 3L Toyota vehicle using Sun road –a- matic XII chassis dynamometer. On both cases the fuels used were diesel (no 2) This is used as a reference fuel & a blend of B10, B20, B30, Initially the engine was tested with pure diesel and later on with different blends of the COME with diesel were prepared, analyzed and compared with Diesel Fuel, and comparison was made to suggest the better option among biodiesel blend. The measuring range and the accuracy of emission analyzer are presented in Table3.4. The sample line of the equipment is connected directly to the exhaust pipe and it is heated to maintain a wall temperature.

Table 3.3. Vehicle specification for exhaust gas measurement

1	Vehicle model	Mercedes Benz truck Type- MB 1017
2	Stroke	4 stroke
3	Number of cylinder	6 cylinder
4	Transmission type	Manual
5	Fuel system	Diesel
6	Chassis number	WDB 380013-15-339123
7	Engine number	3621880102
8	Cooling system	Water cooled

Figure 3.25. Vehicle & emission analyzer for exhaust gas measurement

Table 3.4. FGA-4100 Automotive Emission analyzer main specification [43].

Emission	Measuring range	Accuracy	
		Absolute error	relative error
HC	0-9999ppm	±12ppm vol	±5%
CO	0-9.99%	±0.06% vol	±5%
CO_2	0-20%	±0.5% vol	±5%
O_2	0-25%	±0.1% vol	±5%
NO_x	0-5000ppm	±10ppm	±4%
λ	0.5-3.0	-	-

Table 3.5. Vehicle specification for performance measurement

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

Figure 3.26. Chassis dynamometer and vehicle for performance test

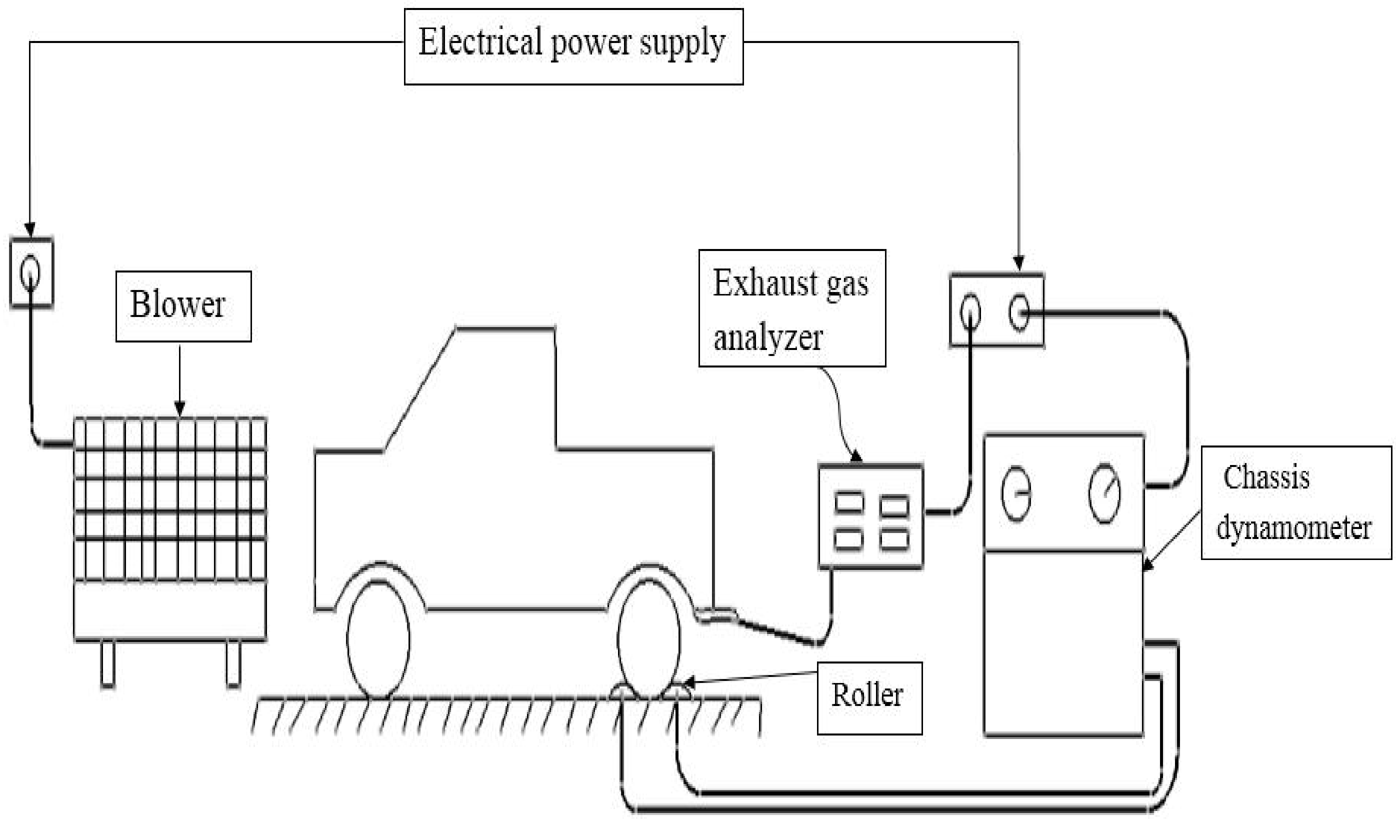


Figure 3.27. Schematic representation for performance and emission test

3.3. Emission &Performance test procedure in diesel vehicle

The Emission gases test was performed on truck vehicle running the engine with no load conditions at different engine rpm connect the emission analyzer & keep it to warm up for 15 min then displays emission gases with respect to engine rpm.

The performance test was performed when the vehicle was driven on the chaises dynamometer and the tractive effort (kN) and wheel power (kW) which is measured at test speed of starting from 15 Km/hr on the sun Road-a-Matic XII chassis dynamometer with 10km/hr interval up to 75km/hr. The experiment was conducted in first gear, second gear, third gear, and fourth gear the time taken for the consumption of fuel was recorded. The performance of the engine with blend of biodiesel and petro diesel can be evaluated by measuring torque, power and its fuel consumption at different speeds. The experiments were conducted for pure diesel fuel & B10, B20, B30 biodiesel blend.

The experiments were conducted as for the steps given below.

1. Fuel blends were prepared by volume.
2. The engine fuel tank was cleaned and filled with the fuel to be tested.
3. The engine was run with diesel fuel for about ten minutes to get warm up.
4. After warming up, the test was conducted for pure diesel at different test speeds then different parameters has been read & record from the dynamometer & also emission test results recorded .
5. And such parameters tractive force and power at the rear wheel were recorded at different speeds at equal intervals in the speed range.

4. RESULT AND DISCUSSION

4.1. Oil content from extraction

Crude oil was extracted from cotton seed by mechanical press machine. From 40kg of cotton seed the yield of oil was 7L which is 17.5% (v/wt.). Oil extraction by mechanical pressing is economical and time saving method.

4.2. Production of biodiesel

From 7L of crude cotton seed oil biodiesel production yield was 5L which is 71.5% by performing transesterification process & by maintaining the proportion of reactants and conditions of reaction as mentioned in table 4.1 given below. The activities like glycerin separation, washing about six times with distilled water and drying by heating up to 100^{o}c for 1 hr were performed. Transesterification reaction was done in proportion of table listed below.

Table 4.1Transterification process

Amount of cottonseed oil (ml)	Molar ratio of alcohol	catalyst (KOH) %	alcohol (Methanol) in (ml)	KOH in(gm)	Reaction time in (minute)	Reaction temperature in (^{o}C)	Settling time in (hr)
500	1:5	1.0	100	5.0	60	65	24

4.2. Result from characterization of blend fuels

Table 4.2. Characterization of blended fuels

S.no	property	B100	B10	B20	B30	ASTM method	ASTM 6751 Standard
1	Density@15°C,(g/cm^3) Density@20°C,(g/cm^3)	0.8911 0.8877	0.8574 0.8539	0.8611 0.8576	0.8641 0.8613	D4052 D4052	0.86-0.9
2	Cloud point, °c	+4	+1	+1	+1	D2500	As report
3	Flash point, °c	178	86	89	90	D93	Min 130
4	Distillation	-	-	-	-	D86	
	IBP, °c	320.0	193.5	196.5	165.5		
	10% volume, recovered °c	331.5	229.0	233.5	240.5		-
	40% volume, recovered °c	334.5	287.5	293.5	302.5		-
	50% volume, recovered °c	335.5	299.5	306.0	315.0		-
	90% volume, recovered °c	361.0	354.0	355.0	358.0		282-362 °c
	95% volume, recovered °c	363.0	367.0	358.0	368.0		-
	FBP, °c	363.0	369.0	363.0	369.0		Max 390 °c
5	Acid value (mg of KOH/gm.)	0.06	0.02	0.04	0.05	D974	0.8mg of KOH/gm.
6	Kinematic viscosity@40 °c	5.9	-	-	-	D445	1.9-6mm^2/s
7	Cetane index	45.3	50.7	50.5	50.5	D976	Min 40 °c
8	UV spectrum (nm)	229	256	256	257		220-300 nm
9	PH	6.85	7.00	6.99	6.99		Approx. To 7 (neutral)

After blending the properties of B10, B20, B30 & pure biodiesel were measured. It's observed that the values are with in ASTM specification. Then performance & emission test were conducted on the vehicle.

4.4 Measurement of exhaust emission

Substances which are emitted to the atmosphere from any opening of the exhaust port of the engine are termed as exhaust emissions. If combustion is complete and the mixture is stoichiometric the products of combustion would consist of carbon dioxide (CO_2) and water vapor only. However, there is no complete combustion of fuel and hence the exhaust gas consists of variety of components, the most important of them are carbon monoxide (CO), CO_2 unburned hydrocarbons (UBHC) and oxides of nitrogen (NOx). Some oxygen and other inert gases would also be present in the exhaust gas.

4.5. Results from emission test

In this section the results of the emission test conducted on CI engine running with diesel and COME are discussed. The main exhaust emissions analyzed in the present investigation are CO, NOx, O_2, CO_2 and HC.

4.6. Tabular & graphical representation for emission test data

Table 4.3. HC Emission in ppm

Engine rpm	500	1000	1500	2000	2500
B0	468	440	435	422	418
B10	460	430	425	410	400
B20	450	418	420	395	390
B30	445	400	390	375	370

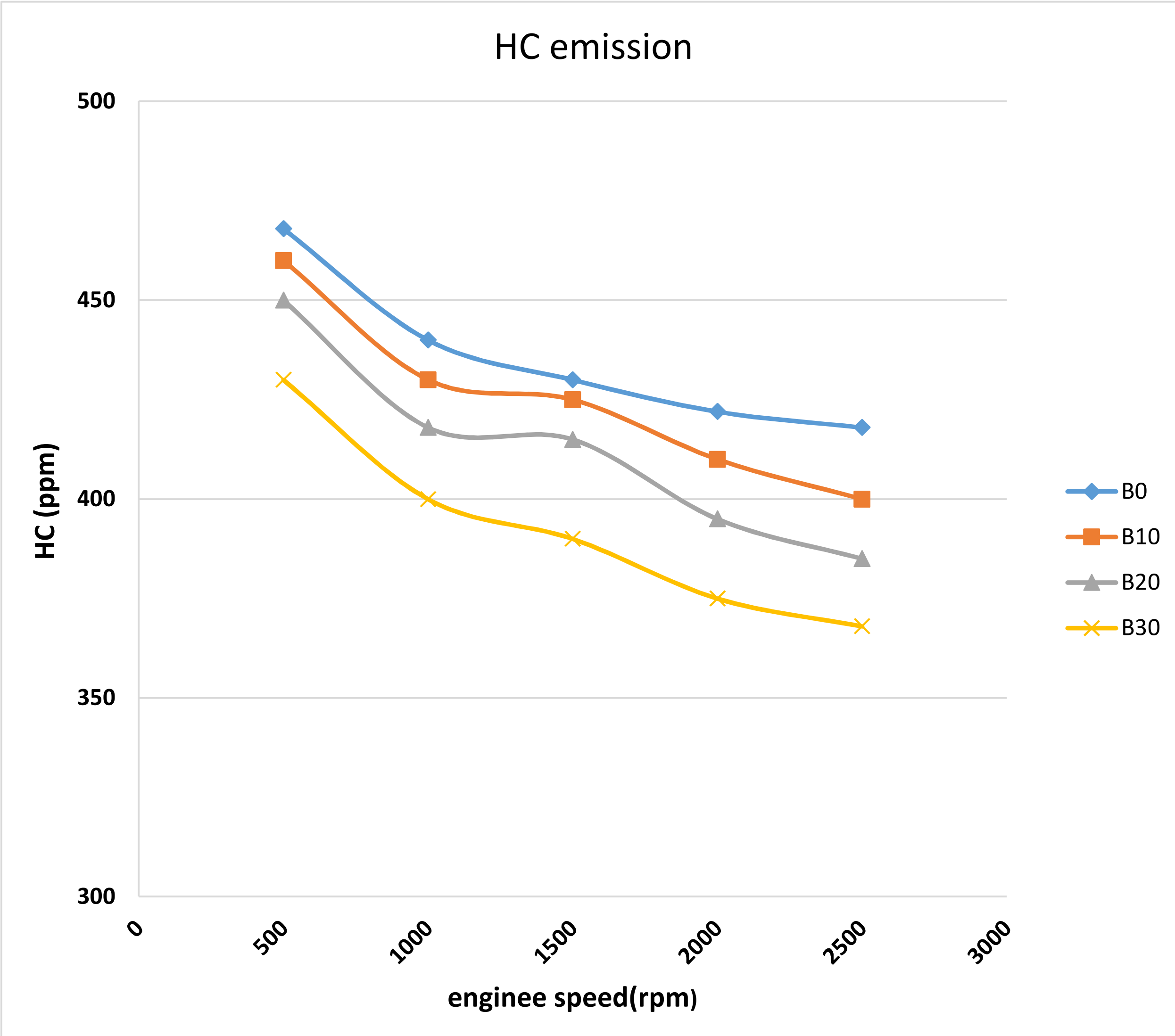


Figure 4.1. variation of HC emission with respect to engine speed

From the above fig 4.1, it is observed that the HC emissions for all blends of biodiesel are lower than that of diesel fuel. Over the range of speed tested the reduction of HC for B10, B20 and B30 at low engine speed 500 rpm is by 2% 4% & 6% and at a speed of 2500 rpm the reduction is by 5%, 7% & 12% respectively when compared to B0. Because biodiesel is oxygenated fuel, one can expect better combustion which is leading to reduction in HC emission.

The measured data of CO emission in %V is given in table 4.4

Table 4.4. CO (%V) test result

Engine rpm	500	1000	1500	2000	2500
B0	0.08	0.065	0.075	0.07	0.06
B10	0.078	0.07	0.065	0.06	0.055
B20	0.075	0.06	0.06	0.045	0.053
B30	0.073	0.06	0.05	0.055	0.051

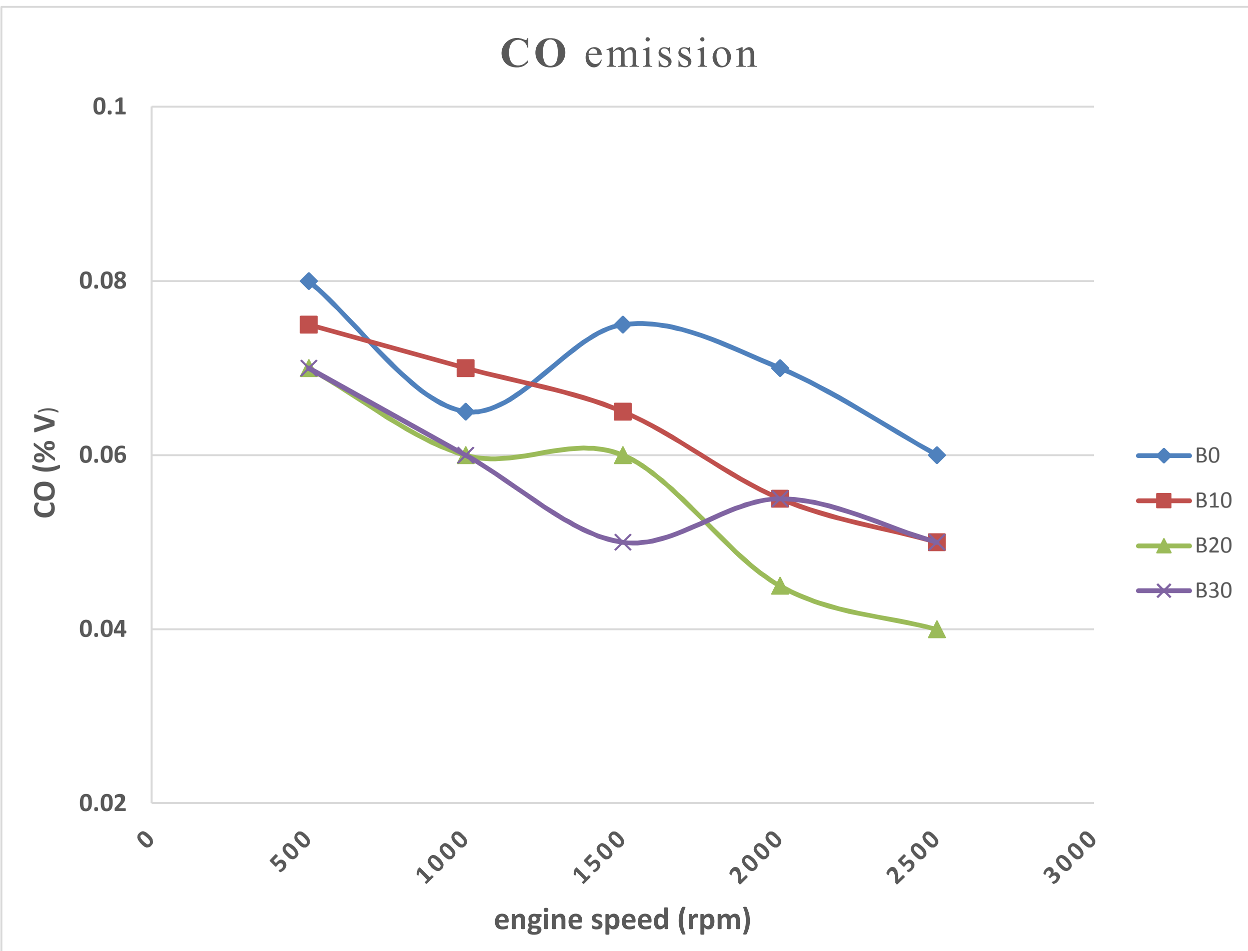


Figure 4.2. variation of CO (%V) emission with respect to engine speed

As shown in fig 4.2. That CO emissions with biodiesel blends is lower than that of the diesel. It's also due to the efficient burning of biodiesel which is an oxygenated fuel. It can be seen that CO emission is decreasing with increasing engine speed. This may be because when the engine speed increases, the air fuel mixing process is better and combustion is more efficient.

At low engine speed 500 rpm the reduction of CO emission is by 3%, 7% and 9% and at a speed of 2500 rpm the reduction is by 9%, 12% and 16% in B10, B20 and B30 respectively when compared to B0.

The measured NO_x emission data is given in table 4.6.

Table 4.5. NO_x emission in ppm

Engine rpm	500	1000	1500	2000	2500
B0	16.5	17	17	17.5	18
B10	17	16	16	16.5	18.7
B20	17.3	17	16	17	19
B30	17.5	17	17.5	18	20

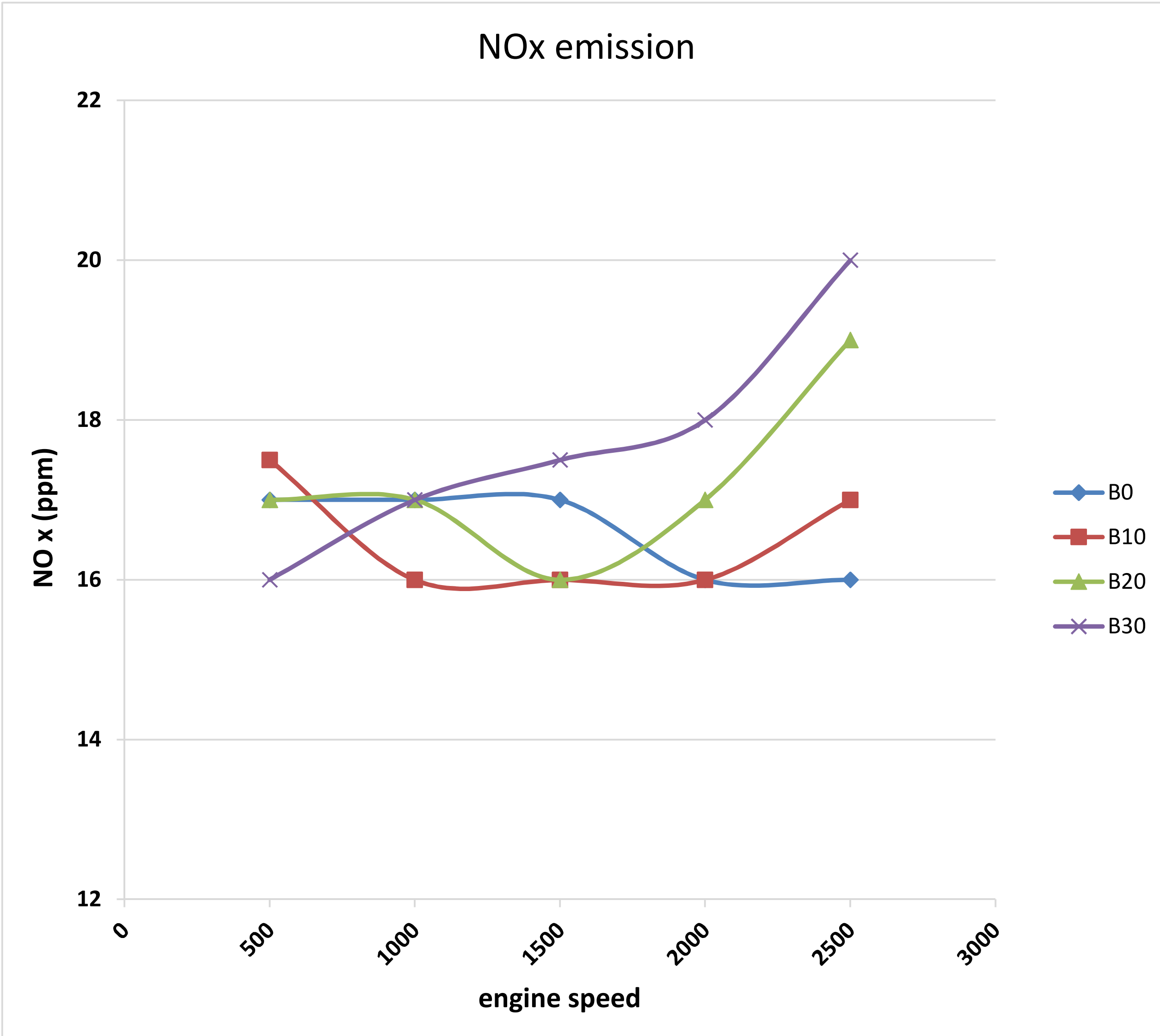


Figure 4.3. variation of NO_x (ppm) emission with respect to engine speed

From the above figure 4.3, it is apparent that the NO_x emission is increasing with increase in the engine speed. The increase in NOx emission at low speed 500rpm is by 2%, 4% & 6% and at a speed of 2500rpm is by 3%, 5%, and 11% in case of B10, B20 and B30 respectively when compared to B0. It is because of the higher temperature in the combustion chamber in the case of biodiesel blends.

The measured data of O_2 emission is given in table 4.7

Table 4.6. O_2 (%v) emission test results

Engine rpm	500	1000	1500	2000	2500
B0	11	10	11	12	12
B10	11.3	12	11	11.5	12.5
B20	11.5	13.2	13.8	14	13
B30	12	14	13	14.5	14

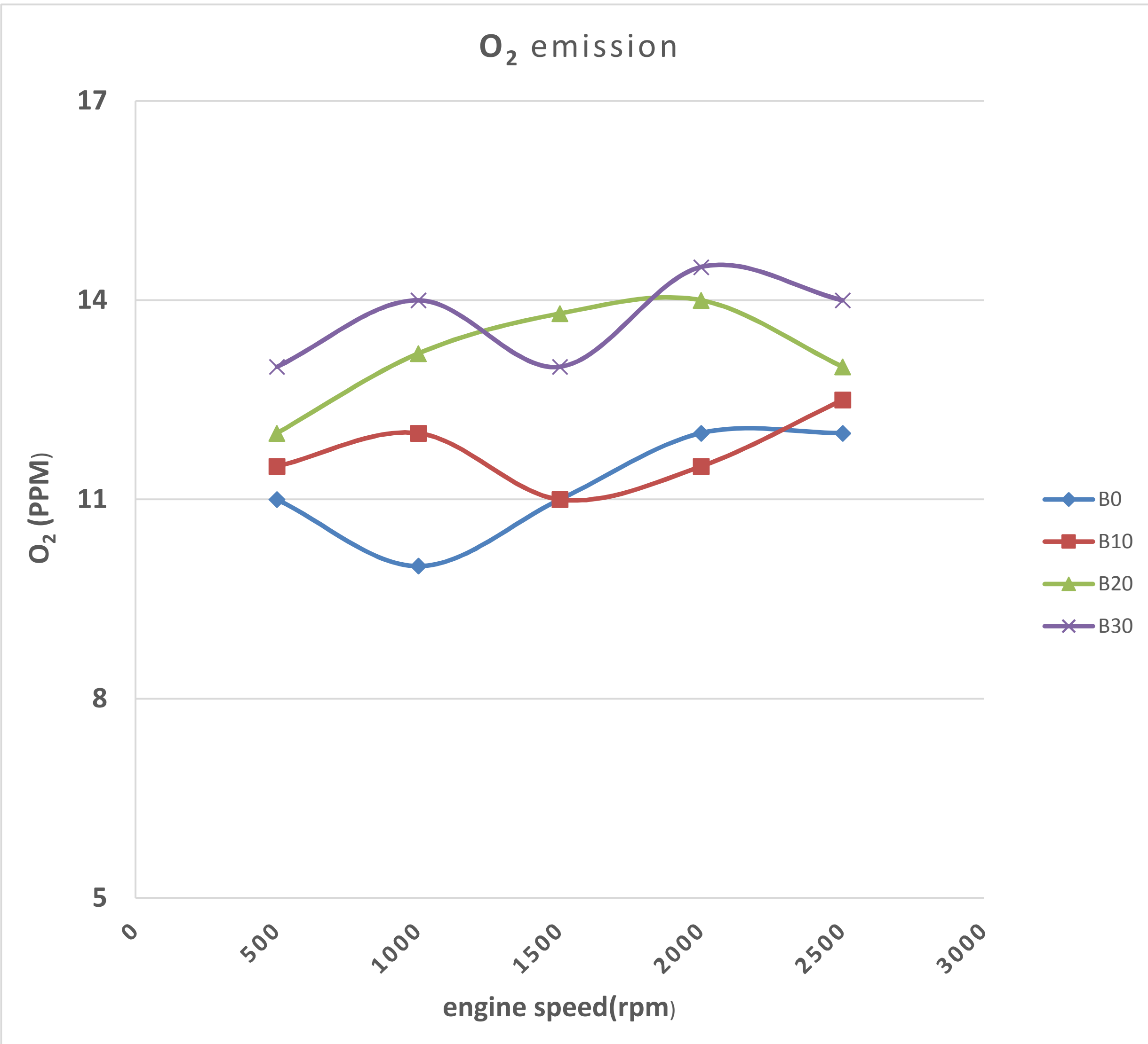


Figure 4.4. variation of O_2 (%v) emission with respect to engine speed

As it is seen in the figure 4.4. That O_2 emission for the blends of biodiesel is higher than that of the diesel. This is because biodiesel is an oxygenated fuel and it contains oxygen of about 11% by weight. High oxygen content leading to complete combustion. The O_2 emission in case of biodiesel blends increased at low speed 500rpm is by 2%, 4% & 9% and at a speed of 2500rpm is by 4%, 8% & 16% respectively in B10, B20 and B30.

The measured data of CO_2 emission is given in table 4

Table 4.7. CO_2 (%v) emission test results

Engine rpm	500	1000	1500	2000	2500
B0	2.75	2.6	2.9	3	3.2
B10	2.7	2.4	2.7	2.65	3.0
B20	2.6	2.8	2.6	2.4	2.8
B30	2.5	2.1	2.3	2.5	2.7

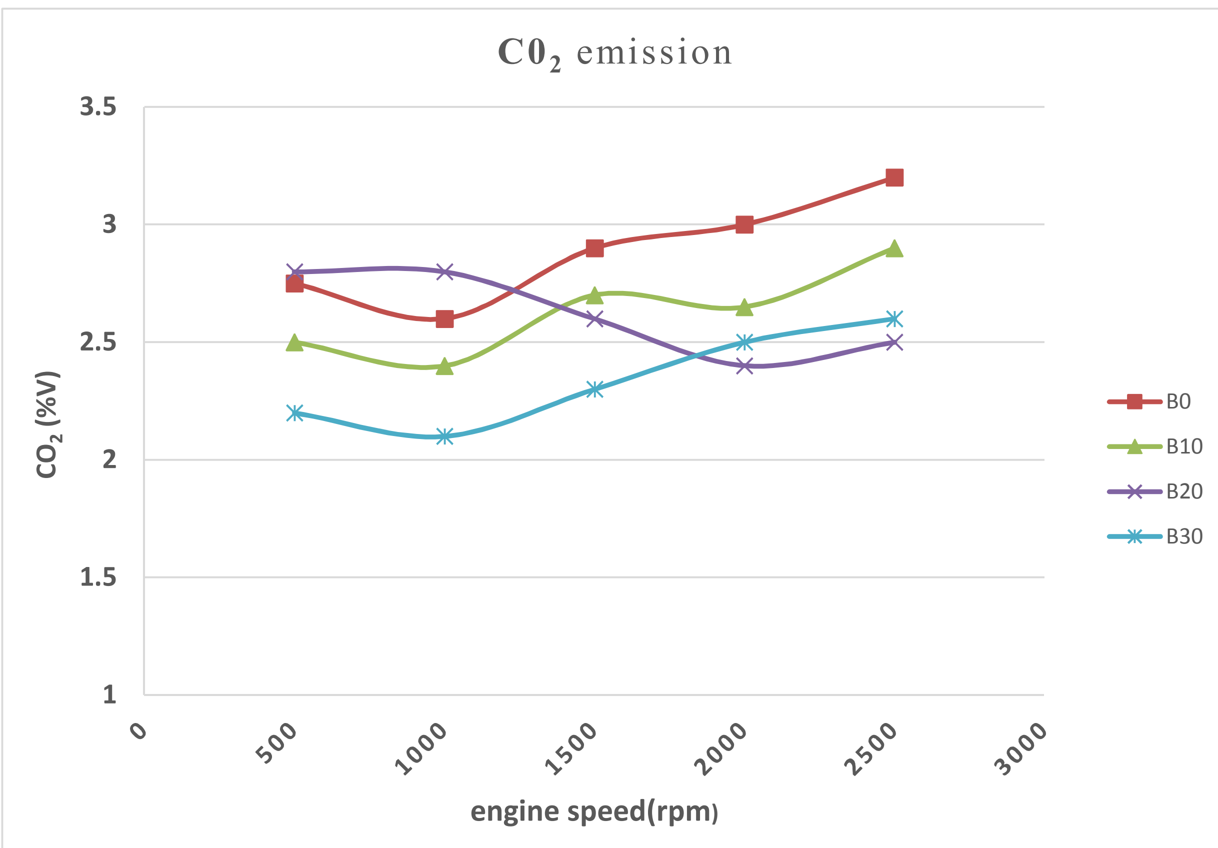


Figure 4.5. variation of CO_2 (%v) emission respect to engine speed

It can be seen that the CO_2 emission compared to diesel fuel decreased for all biodiesel blends. The reduction of CO_2 at low engine speed 500rpm is by 2%, 6% & 10% and at a speed of 2500 rpm is by 8%, 13% and 16% in B10, B20, and B30 respectively compared to B0. This may be due to the fact that biodiesel has a lower elemental carbon to hydrogen ratio than diesel fuel. The burning of blend fuels with air will therefore form lower CO_2 emission than diesel fuel.

4.7. Vehicle Performance test

The performance of diesel vehicle was tested using chassis dynamometer. The performance parameters like tractive force in (kN) & wheel power in (kW) were measured.

Tractive effort

Tractive force or tractive effort or traction is the force applied between the tire and road surface to move a car or any vehicle. The maximum permissible traction force that can be applied to the wheels is governed by two things: the weight of the vehicle and the adhesion coefficient between the tire and the road surface. More the weight and the adhesion coefficient more amount of tractive force can be applied to the wheels without causing slip between the tires and road.

$$F_{tr} = \frac{T_W}{r_W} \qquad \text{Eq (4.1)}$$

$T_W = F_{tr} \times rw$ Where, Tw = wheel torque, F_{tr} = tractive force, r_w = radius of the wheel

Power at wheels

The power that comes to the wheels is the engine power multiplied by the efficiency of the transmission.

$$P_W = \eta P_p \qquad \text{Eq (4.2)}$$

Where P_w = wheel power

η_t = efficiency of the transmission

$P_{p.}$ = engine power

The wheel power data for B0 and B10 is given in table 4.8 and for B20 & B30 is given In table 4.9.

Table. 4.8. Wheel power for B0 & B10

Wheel power for B0 & B10 (kW)								
V. speed (km/hr.)	1st gear		2nd gear		3rd gear		4th gear	
	B0	B10	B0	B10	B0	B10	B0	B10
15	12	10	11	9	9	7	8	6
25	16	14	15	13	13	11	12	8
35	18	12.5	17	15	15	14	13	10
45			19	16	16	14.5	14.5	12
55			18.5	17	16.5	16	17	13
65			17.5	16.5	16	16.3	15.5	14.5
75			16	14.5	15	13.5	14	13

Table. 4.9. Wheel power for B20 & B30

Wheel power for B20 & B30 (kW)								
V. speed (km/hr.)	1st gear		2nd gear		3rd gear		4th gear	
	B20	B30	B20	B30	B20	B30	B20	B30
15	11	9	10	8	8	6	7	5
25	15	12	14	12	12.5	10	9	7
35	14	11	16	14	14.5	13	11	9
45			17	15	15	13.5	13	11
55			17.3	16	17.3	15.3	14	12
65			15	13	14	12	14.5	11
75			13	10	11	9	13	9

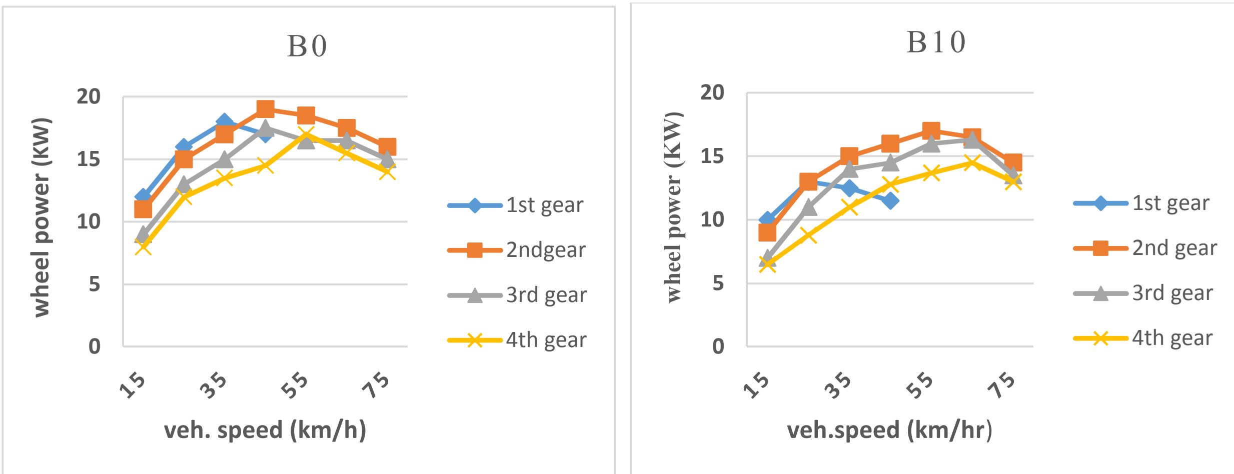


Figure 4.6. Wheel power for B0&B10

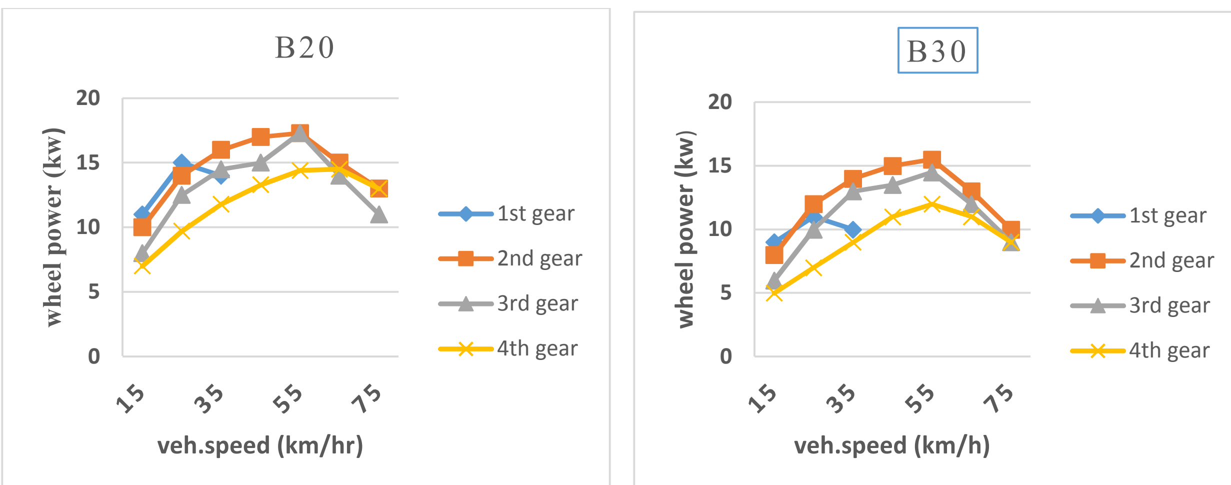


Figure 4.7. Wheel power for B20 &B30

Table.4.10. Tractive effort data for B0 & B10

Tractive effort for B0 & B10 (kN)								
V. speed (km/hr.)	1st gear		2nd gear		3rd gear		4th gear	
	B0	B10	B0	B10	B0	B10	B0	B10
15	3	2.6	2.5	2.2	2.1	1.6	1.8	1.3
25	2.5	2.4	2	1.6	1.5	1.3	1.3	1.2
35	1	0.7	1.5	1.1	1.8	1.4	1.5	1.2
45			0.7	0.4	1.6	1.3	1.3	1.1
55			0.5		1.0	0.9	1.0	0.9
65					0.8	0.5	0.8	0.5
75							0.6	0.4

Table. 4.11Tractive effort data for B20 & B30

Tractive effort for B20 & B30 (kN)								
V. speed (km/hr.)	1st gear		2nd gear		3rd gear		4th gear	
	B20	B30	B20	B30	B20	B30	B20	B30
15	2.8	2.5	2.4	2.0	1.8	1.5	1.5	1.2
25	2.5	2.2	1.8	1.5	1.5	1.0	1.3	1.0
35	0.8	0.5	1.3	0.9	1.6	1.3	1.4	1.1
45			0.5	0.3	1.5	1.0	1.3	1.0
55			0.3		1.0	0.7	0.9	0.8
65					0.6	0.3	0.7	0.4
75							0.5	0.3

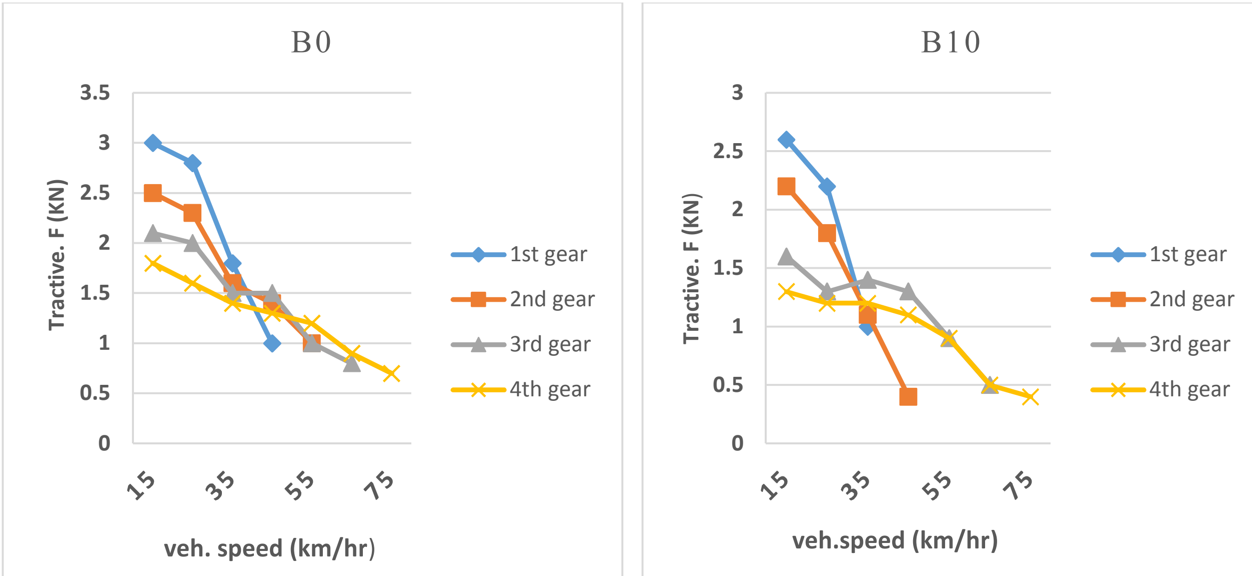


Figure 4.8. tractive effort for B0 & B10

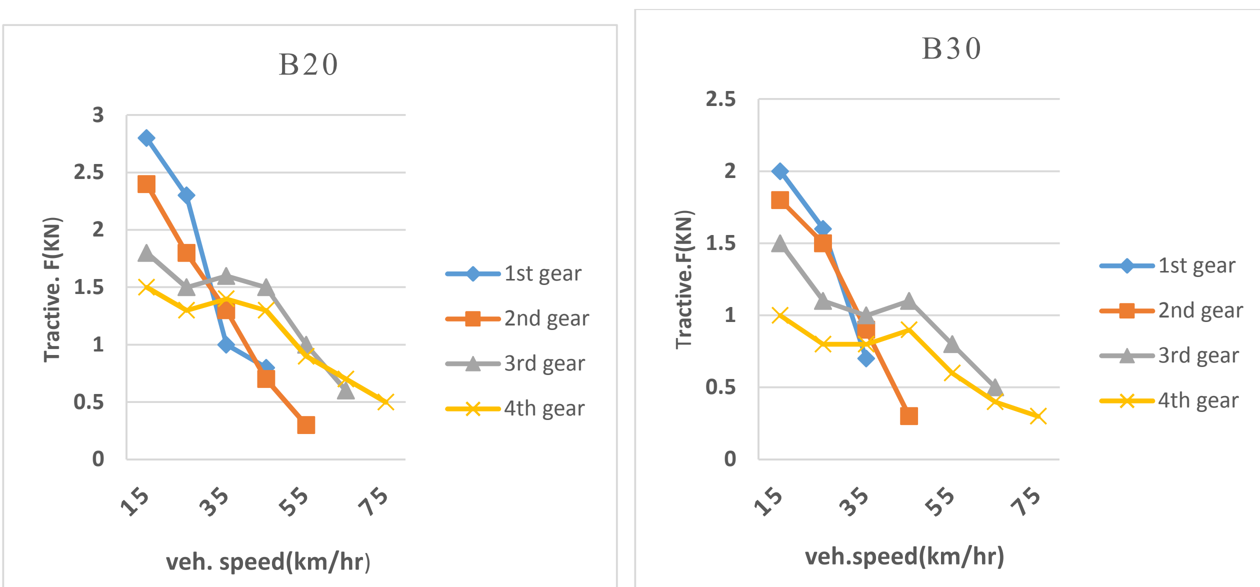


Figure 4.9. tractive effort for B20 & B30

Table.4.12. fuel consumption data for B0,B10,B20 and B30

Fuel consumption					
		B0	B10	B20	B30
Vehicle speed (km/hr)	m_f (ml)	t(sec)	t(sec)	t(sec)	t(sec)
15	10	20	18	17	15
25	10	15	13.3	12.5	11.5
35	10	10.5	10	9.2	8.5
45	10	9	8	7	6

The engine brake torque and brake power are calculated by using the measured wheel power and wheel torque from chassis dynamometer. Then the brake specific fuel consumption is calculated by measuring the fuel flow ratio.

Table .4.13. Wheel torque for B0 & B10

Wheel torque for B0 & B10 (Nm)								
V. speed (km/hr)	1st		2^{nd}		3^{rd}		4^{th}	
	B0	B10	B0	B10	B0	B10	B0	B10
15	1008	936	900	792	756	576	648	468
25	900	864	720	576	540	468	468	432
35	360	252	540	396	648	504	540	432
45			252	144	576	468	468	396
55			180		360	324	360	324
65					255	180	255	180

Table 4.14. Wheel torque for B20 & B30

Wheel torque for B20 & B30 (Nm)								
V. speed (km/hr)	1st		2nd		3^{rd}		4^{th}	
	B20	B30	B20	B30	B20	B30	B20	B30
15	1008	900	864	720	648	540	540	432
25	900	792	648	540	540	360	468	360
35	288	180	468	324	576	468	504	396
45			180	108	540	360	468	360
55			108		360	252	324	288
65					216	108	252	144

The chassis dynamometer does not have engine revolution counter, it rather displays wheel speed in Km/hr. Therefore it is 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.

$$N = \frac{(2.65 \text{ x } V \text{ x } g_r \text{ x } a_r)}{r_w} \text{..........} \quad \text{Eq (4.3)}$$

Where N =engine speed (rpm)

V = Vehicle speed (km/hr)

g_r= gear box ratio

a_r = axle ratio

r_w = wheel radius taken as 0.36

Table.4.15, gear box gear ratio & transmission efficiency for Toyota Hilux

Gear	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	Final drive
Gear ratio	3.5	2.06	1.44	1.00	0.81	4.0
Efficiency	0.80	0.825	0.85	0.87	0.90	0.92

Source: - http://en.Wikepidia.org/wiki/Toyota transmission

Brake Power (P_b): is an engine performance parameter. The power developed by an engine and measured at the output shaft is called the brake power (b_p) and is given by, $bp = \frac{2\pi NT}{60}$ Where, *T* is torque in N-m and *N* is the rotational speed in revolutions per minute & also we can express brake power as the following:-

$$Pb = \frac{Pw}{\eta t} \qquad \text{eq (4.4)}$$

Where: P_b- brake power, Pw- wheel power, ηt - gear box efficiency

Table.4.16. brake power for B0 & B10

Brake power for B0 & B10 (kW)								
Engine speed (rpm)	1^{st}		2^{nd}		3^{rd}		4^{th}	
	B0	B10	B0	B10	B0	B10	B0	B10
1545	16	13	14	12	12	9.3	10.7	8
2569	21	18.7	19	17	17.3	14.7	16	10.7
3606	24	16.5	21	20	20	18.5	17.3	13.3
4637			23	21..3	21.3	19.3	19.3	16
5668			23.5	22.7	22	21.3	22.5	17.3
6698			23	22	21	21	20.7	19.3
7730			21	19.3	20	18	18.7	17.3

Table.4.17. brake power for B20 & B30

Brake power for B20 & B30 (kw)								
Engine speed (rpm)	1st		2nd		3rd		4th	
	B20	B30	B20	B30	B20	B30	B20	B30
1545	14.7	12	13	10.7	11	8	9.3	6.7
2569	20	16	18	16	16	13.3	12	9.3
3606	18.7	14.7	21	18.7	18	17.3	14.7	12
4637			22.7	20	20	17	17.3	14
5668			23	21.3	23	20.4	18.7	16
6698			20	17.3	18.7	16	18	14
7730			17.3	13.3	14.7	12	17.3	12

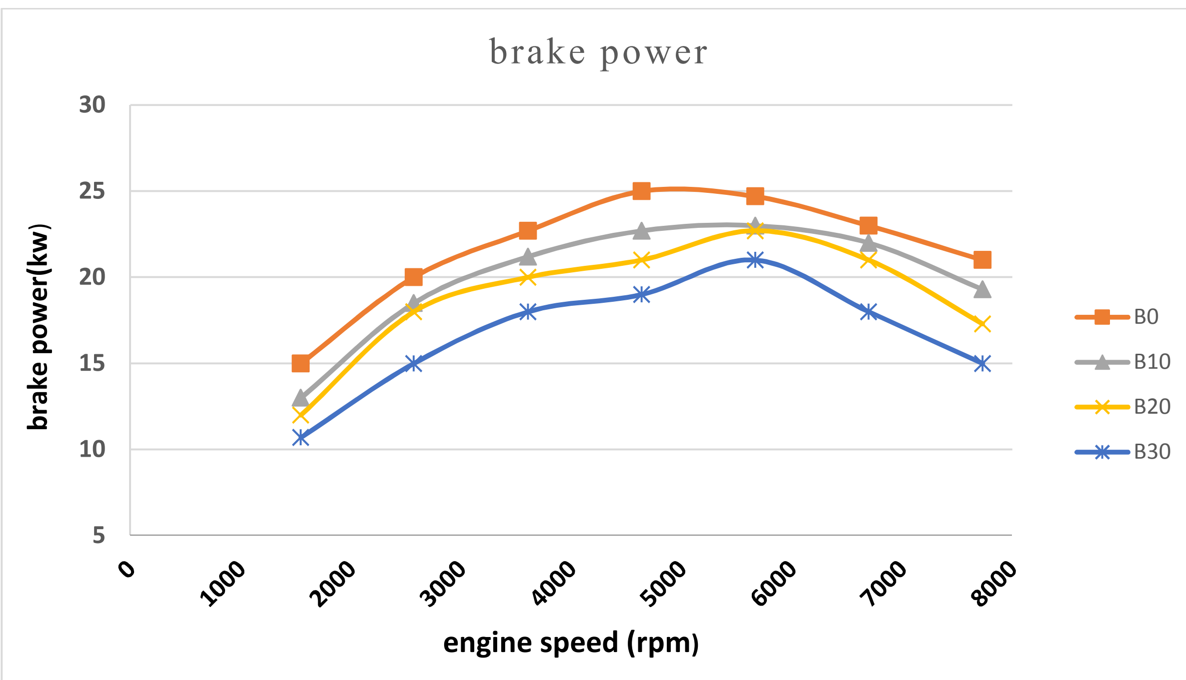


Figure.4.10. Variation of brake power with respect to engine speed

It can be seen that from the figure 4.10 that the biodiesel blend fuels produced lower BP than diesel fuel. Brake power increases with increasing engine speed until 5668 rpm and then power starts to decrease. In case of biodiesel blended fuels B10, B20 & B30 the average reduction of BP is by 6%, 8% & 11% compared with diesel fuel. The lower brake power in all blended fuels compared to diesel fuel is mainly due to their lower heating values. Therefore more volume of biodiesel is needed to produce equivalent power output as compared to diesel.

Brake Torque (T_b):-is the torque available at the 'output shaft' of the engine.

.

$$Pb = \frac{2\pi NT}{60}$$

$$T_b = \frac{P_b}{\omega} = \frac{60 \times P_b}{2\pi \times N} \quad \ldots\ldots\ldots . \quad in \quad ' Nm '$$

$$T_b = \frac{60 \times P_b \times 1000}{2\pi \times N}$$ P_b in 'kW'; N in 'rpm'; and T_b in 'Nm

Table.4.18. brake torque for B0 & B10

Brake torque for B0 & B10 (Nm)								
Engine speed (rpm)	1st		2nd		3rd		4th	
	B0	B10	B0	B10	B0	B10	B0	B10
1545	92	88	97	96.5	93	90	85	80
2569	90	86	103	98	94	92	86	82
3606	84	82	107	104	98	96	87	83
4637			105	100	93	91	78	77
5668			99	95	87	84	76	73
6698			94	91	78	74	73	68
7730			85	80	72	70	68	61

Table.4.19. brake torque for B20 & B30

Brake torque for B20 & B30 (Nm)								
Engine speed (rpm)	1^{st}		2^{nd}		3^{rd}		4^{th}	
	B20	B30	B20	B30	B20	B30	B20	B30
1545	90	86	95	85	91	86	78	75
2569	83	80	94	91	93	89	81	77
3606	80	73	100	92	96	90	82	78
4637			93	85	94	91	79	72
5668			87	80	91	87	74	67
6698			83	74	87	84	69	62
7730			79	70	85	79	64	60

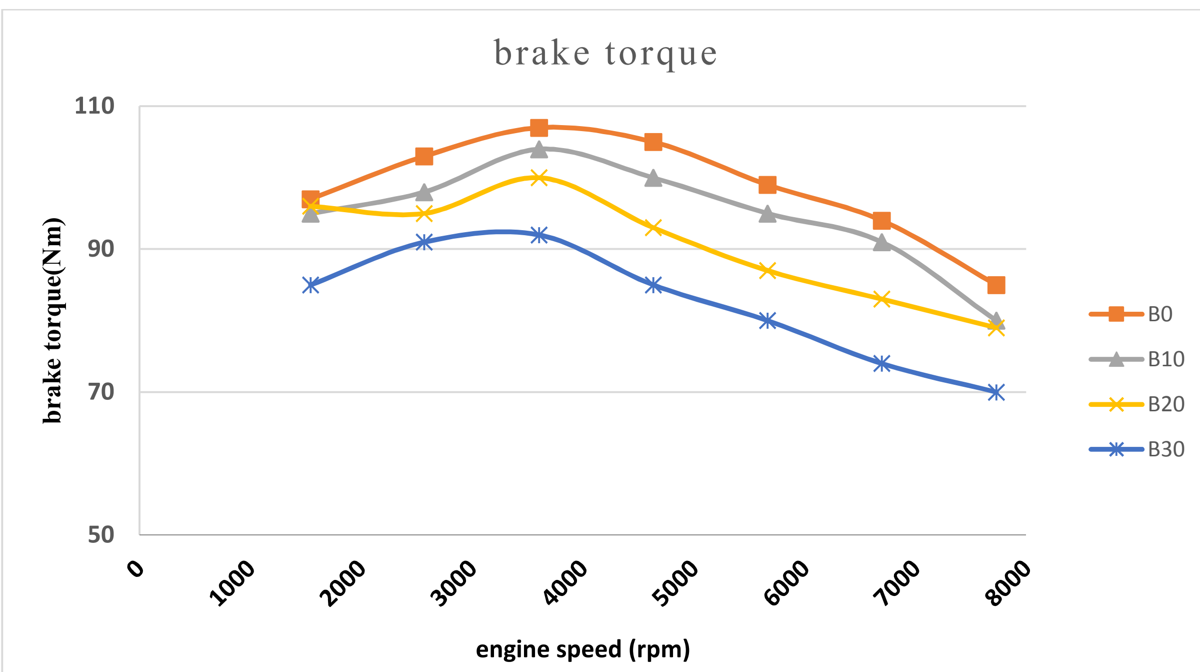


Figure.4.11. Variation of brake torque with respect to engine speed

Brake torque initially increases with increasing of engine speed until it reaches 3606 rpm and then decreases with further increasing engine speed for all test fuel samples.

However, the torque of the engine fuelled with diesel fuel is higher than that of blended fuels. The reason for the reduction of torque with blends can be the lower heating value of the fuel. For all blended test fuels the average torque reduction compared to diesel fuel is by 5%, 7% & 12% respectively.

Fuel consumption

Fuel consumption is measured in two ways: (a) the fuel consumption of an engine is measured by determining the volume flow in a given time interval and multiplying it by the specific gravity of the fuel which should be measured occasionally to get an accurate value. (b) Another method is to measure the time required for consumption of a given mass of fuel.

Brake specific fuel consumption (*bsfc*): is the amount of fuel consumed by the engine in 'kilogram per hour (kg/h)' to develop a brake power (P_b) of one kilowatt (kW) while running at a constant engine speed (N) in 'rpm'. It is an engine performance parameter which mainly determines, the 'fuel consumption' or the 'fuel economy' of the engine.

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

Brake specific fuel consumption (bsfc) $= \frac{\text{mass flow rate}}{Brake\ power}$ in kg/kwh

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.

$$\text{bsfc} = \frac{mj\left(\frac{gm}{se}\right) x\ 3600}{Pb} \left(\frac{gm}{kwhr}\right) \ldots\ldots\ldots\ldots \text{Eq (4.5)}$$

Table.4.20. bsfc for B0 & B10

bsfc for B0 & B10 (gm/kwhr)						
Engine speed(rpm)	B0			B10		
	t (sec)	m_f (ml)	bsfc	t (sec)	m_f (ml)	bsfc
1545	18.5	0.65	205	16.5	0.7	215
2569	17.0	0.70	200	15	0.74	210
3606	16	0.75	185	14.5	0.8	200
4637	15	0.8	180	13	0.85	185
5668	14	0.84	175	12	0.9	196
6698	13	0.9	182	11	0.85	212
7730	12	0.95	210	10	0.8	218

Table.4. 21.bsfc for B20 & B30

bsfc for B20 & B30 (gm/kwhr)						
Engine speed(rpm)	B20			B30		
	t (sec)	m_f (ml)	bsfc	t (sec)	m_f (ml)	bsfc
1545	15	0.75	225	13	0.8	240
2569	14.5	0.78	220	12.5	0.84	235
3606	13	0.8	216	12	0.9	222
4637	12	0.85	205	11	0.95	216
5668	11	0.9	215	10	1.0	230
6698	10	1.0	222	9.5	1.3	235
7730	9	0.9	227	9	0.95	255

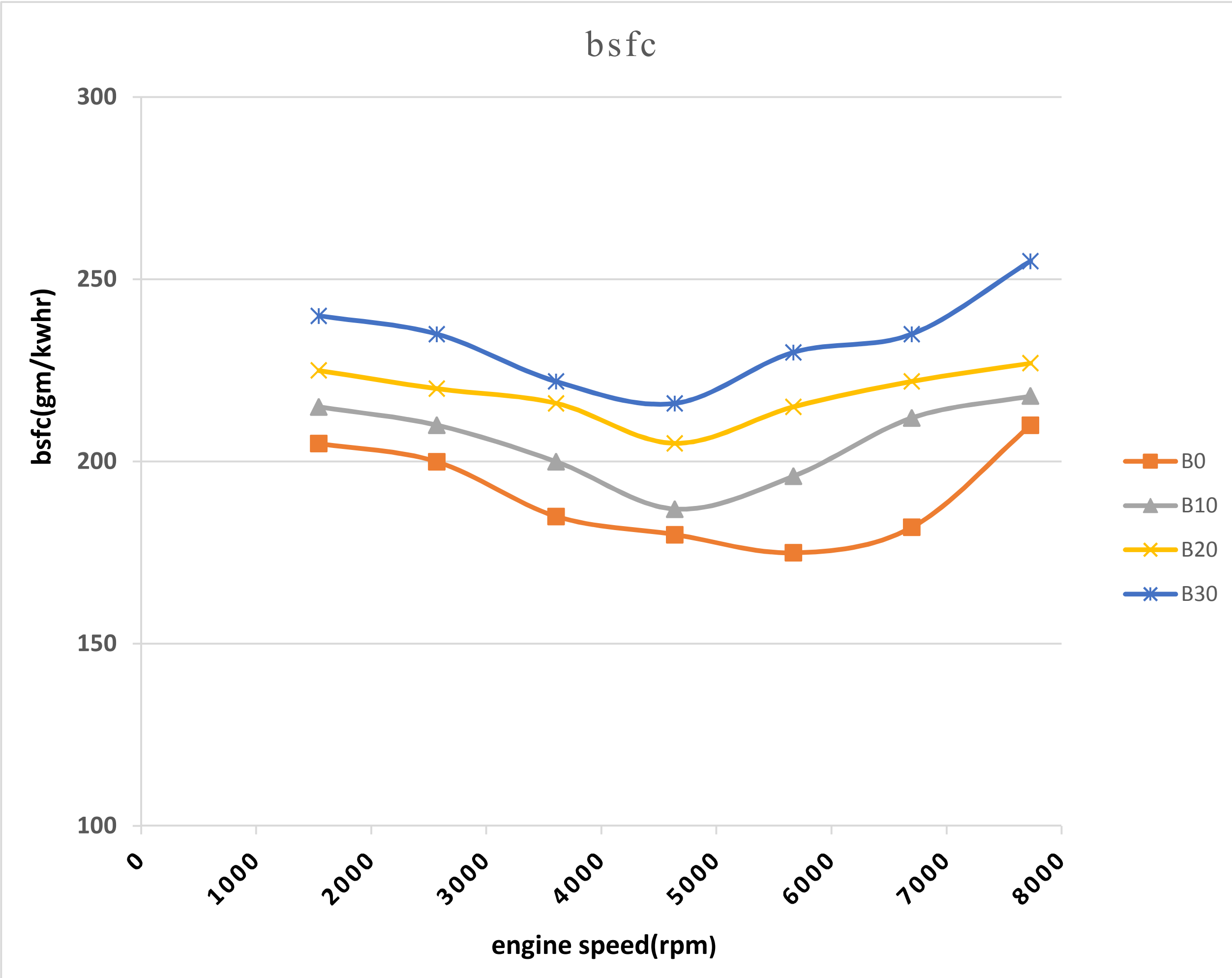


Figure.4.12. variation of bsfc with respect to engine speed

From the figure 4.12 one can see that diesel fuel had the lowest bsfc and the bsfc of blended fuel is increasing with increase in biodiesel percentage in the blends, this is mainly due to the lower heating value of the biodiesel. The average bsfc increment for blended fuel is by 4%, 8% and 20% respectively for B10, B20 and B30 when compared to B0.

The fuel consumption in L/km is calculated from the data in table 4.12

Table 4.22. bsfc in L/km

	bsfc (L/km)			
Vehicle speed Km/hr	B0	B10	B20	B30
15	0.12	0.14	0.15	0.17
25	0.096	0.108	0.115	0.125
35	0.094	0.103	0.112	0.13
45	0.088	0.1	0.116	0.14

Engine performance

The table 4.21 & 4.22 given below represented by scale gives the data of brake power, brake torque and bsfc of the engine at different speed to get the exact value of each parameter multiplied the data with its scale.

Table.4.23. performance data for B0 &B10

B0				B10			
1:1	1:0.5	1:2	1:25	1:1	1:0.5	1:2	1:25
Engine speed rpm	P_b (kw)	T_b (Nm)	bsfc (gm/kwhr)	Engine speed rpm	P_b (kw)	T_b (Nm)	bsfc (gm/kwhr)
1545	30	48.5	8.5	1545	26	47.5	8.8
2569	40	51.5	8	2569	37	48	8
3606	44	53.5	7.4	3606	42	50	8
4637	47	52.5	7.2	4637	44	51	7.5
5668	46	49.5	7	5668	46	48	7.4
6698	45	47	8	6698	44	45.5	8
7730	40	42.5	8.5	7730	38	40	9

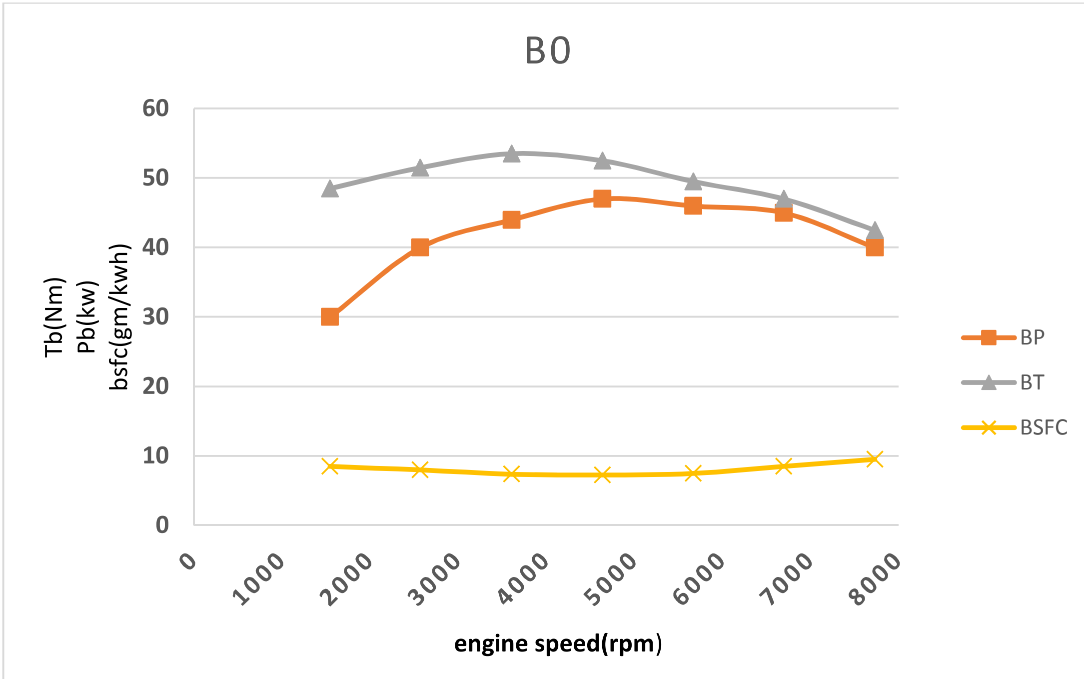


Figure.4.13. performance of B0

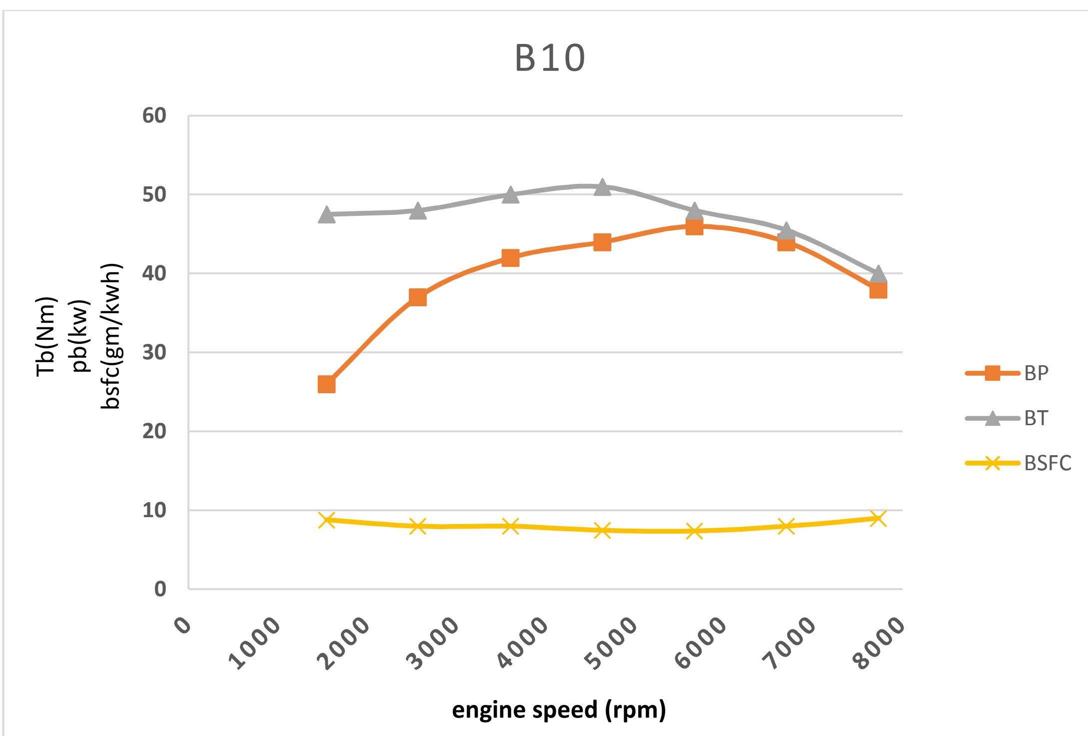


figure 4.14. performance of B10

Table 4.24. performance data for B20 & B30

B20				B30			
1:1	1:0.5	1:2	1:25	1:1	1:0.5	1:2	1:25
Engine speed(rpm)	P_b (kw)	T_b (Nm)	bsfc (gm/kwhr)	Engine speed(rpm)	P_b (kw)	T_b (Nm)	bsfc (gm/kwhr)
1545	24	47	10	1545	20	42	11
2569	34	48	8.5	2569	30	45	8.5
3606	40	49	8	3606	35	46	8
4637	42	47.5	8	4637	37	42.5	9
5668	43	46.5	9.5	5668	36	40	10.5
6698	40	45	10	6698	33	37	12
7730	34	39.5	11	7730	30	35	13

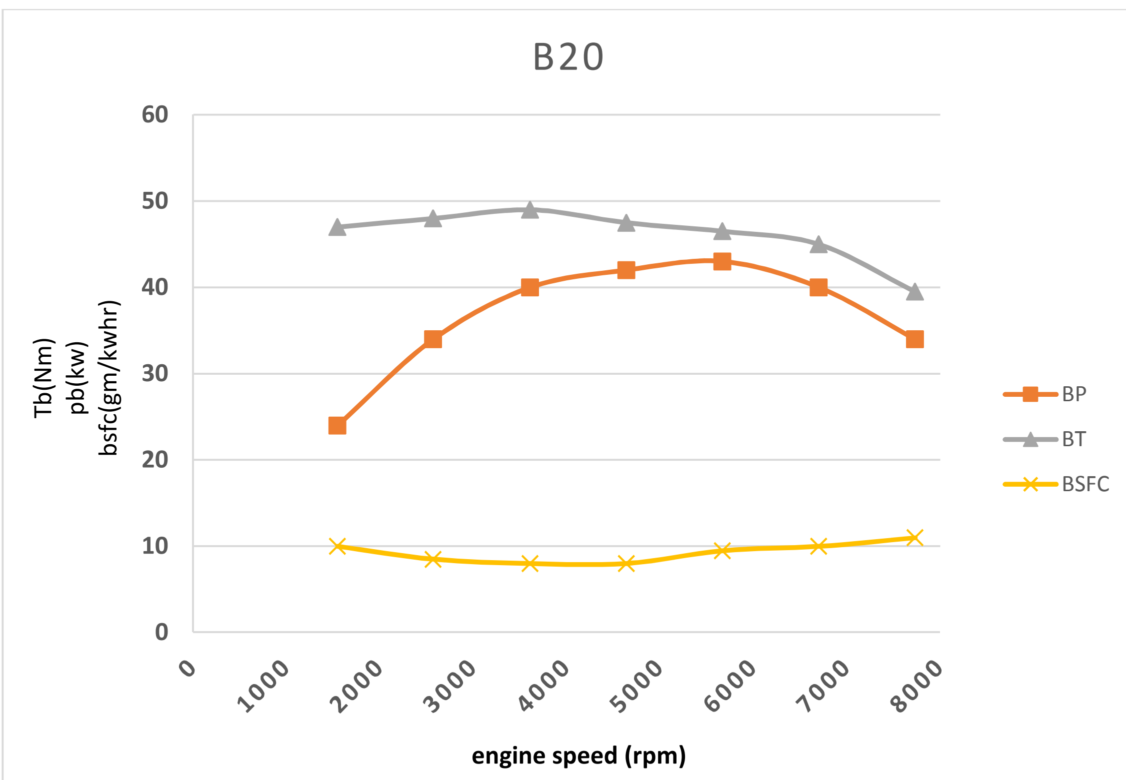


Figure 4.15. Performance of B20

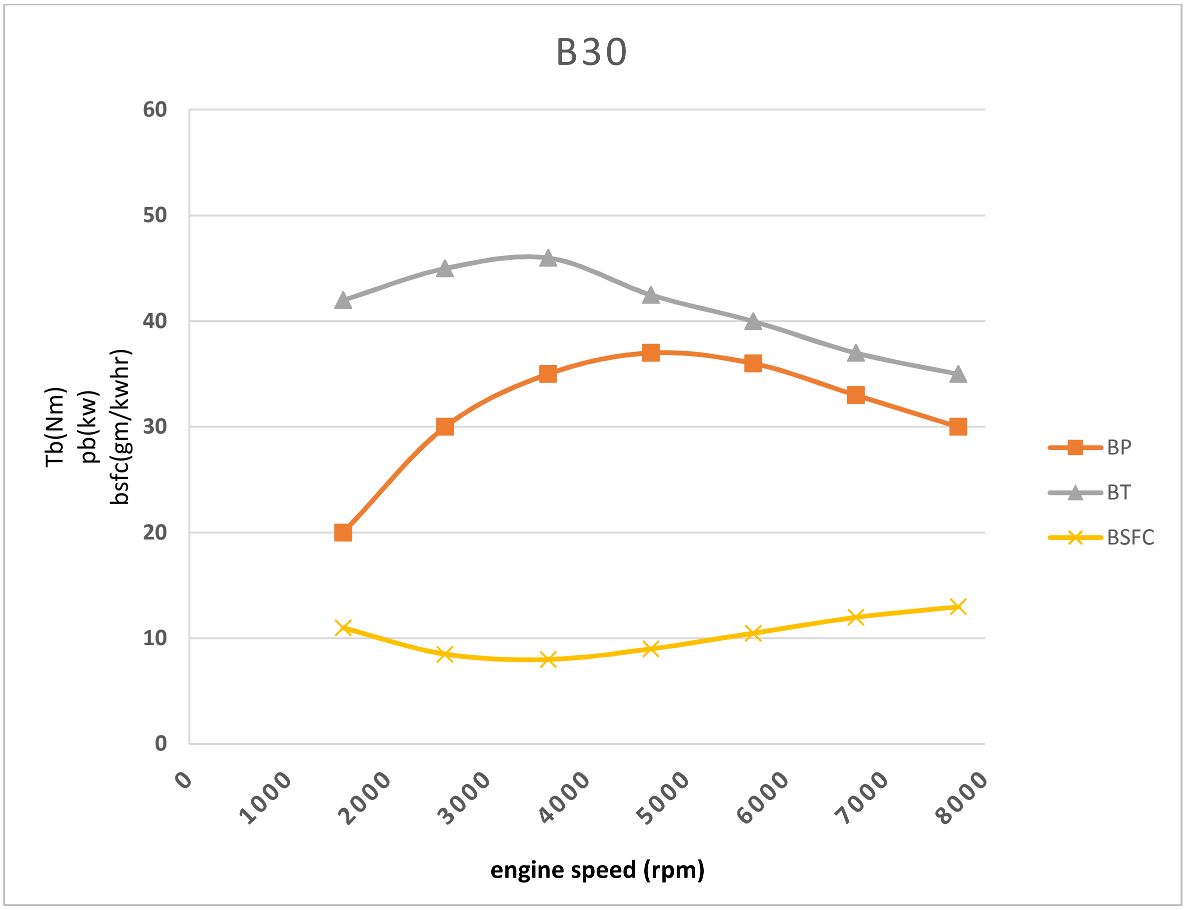


Figure 4.16.performance of B30

The above four figure, fig 4.13, 4.14, 4.15, 4.16 indicate that the performance of the engine with B0, B10, B20 and B30 respectively. The comparison was made by comparing the brake power, brake torque and fuel consumption with engine speed. As a result when the percentage of blend increase brake torque and brake power decreases and brake specific fuel consumption increases with the increase in engine speed. This will be because of higher viscosity and lower heating value of biodiesel blends.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Various experiments were conducted in this thesis work with the aim of testing the performance & emission of cotton biodiesel in diesel vehicles. Pure biodiesel was not used because it is found that the viscosity of cotton biodiesel is still higher than petro diesel. So the blends of biodiesel B10, B20 and B30 were used for testing. From the results it is observed that engine performance when fuelled with the biodiesel blends is comparable to that when fuelled with petroleum diesel. The fuel consumption when fuelled with the biodiesel blend is observed to be higher than when fuelled with petroleum diesel, since a little more biodiesel must be supplied to the engine to produce an equivalent amount of work. The conclusions are summarized as follows.

1. The properties of cotton seed biodiesel and its blends conform to ASTM D6751 standards.
2. The torque & power performance get reduced and fuel consumption increased as the percentage of biodiesel in the blends increase. This is due to the fact that biodiesel has lower heating value compared to petro diesel.
3. The biodiesel blends produced lower emission with drop in CO, CO_2 and HC emission while NOx & O_2 Emissions are show on a little increment compared to the conventional diesel. This is due to the fact that biodiesel is a green and oxygenated fuel and contains less carbon molecules. The oxygen content in the biodiesel results in better combustion and increases the combustion chamber temperature which leads to increase NOx emissions.
4. the results obtained in this thesis work suggests that cotton seed biodiesel blend can be used in an unmodified diesel engine since their performance and emission characteristics were very close to that of diesel and it is environmental friendly with reduced emissions.

5.2. Recommendations

Recommendations are as follows

1. It is recommended to use biodiesel to save environment and foreign exchange. Government has to encourage the people in that direction.
2. It is recommended that the department has to establish research facilities to conduct research on biofuels.
3. It is recommended to use the valuable by products of transesterification process like cake which can be used as cattle feed and glycerin which can be used in cosmetics and other applications.

5.3. Future work

In this work experiments were conducted only on B10, B20 and B30.so the work is to be extended to higher blend ratios to understand the overall behavior of cotton seed biodiesel. Additional research has to be done to analyze the effects of various engine operating parameters like injection pressure, injection timing, turbocharging, EGR etc. there is also a need to find the ways to reduce NO_x emissions which is a major problem with biodiesel.

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APPENDEX

Cost analysis

S. No	**Material**	**Unit**	**Quantity**	**Unit price**	**Total price (birr)**
1	methanol	liter	2	200	400
2	Cotton seed	kg	40	10	400
3	KOH	kg	0.5	660	660
4	Distilled water	liter	25	16	400
5	Characterization of the biodiesel.	----	-----	-----	5,700
5	Diesel fuel	liter	25	15	375
7	Jeri can (plastic)	psc	3	20	60
8	Transport cost	-----	-	------	1000
9	Others	-----	-		500
10	Soap	litre		-	40
11	Rag	kg	1	20	20
Total					**9,555.00**

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ETHIOPIAN PETROLEUM SUPPLY ENTERPRISE

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TEST REPORT

S.N.	Property	Test method (ASTM)	EPSE Diesel limits	ASTM D6751* limit for B100	Test results: Pure biodiesel result	B10	B20	B30
1.	Density@15°C, g/ml	D4052			0.8911	0.8574	0.8611	0.8648
	Density@20°C, g/ml	D4052			0.8877	0.8539	0.8576	0.8613
2.	Distillation	D 86						
	IBP, °C		-		320.0	193.5	196.5	165.5
	10% volume, recovered, °C		-		331.5	229.0	233.5	240.5
	40% volume, recovered, °C		-		334.5	287.5	293.5	302.5
	50% volume, recovered, °C		-		335.5	299.5	306.0	315.0
	90% volume, recovered, °C		282 - 362		361.0	354.0	355.0	358.0
	95% volume, recovered, °C		-		363.0	367.0	358.0	368.0
	FBP, °C, max		390		363.0	369.0	363.0	369.0
3.	Flash Point (PMCC), °C	D 93	Min. 60	Min. 93	178	86	89	90
4.	Cloud point, °C	D2500	Max. +5	Report	+4	+1	+1	+1
5.	Kinematic viscosity at 40 °C	D 445	1.9-5.5	1.9-6.0	5.9	-	-	-
6.	Total Acidity, mg KOH/g	D 974			0.06	0.02	0.04	0.05

- The results in this report relate only to the sample tested.

* D6751 is the limit for B100 to be used for blending with petro diesel up to B20.

Liability

Ethiopian Petroleum Supply Enterprise, its Laboratory, its Servants or agents Shall not be held liable for any damages, loss, claims or expenses direct or indirect howsoever caused, arising in connection with the laboratory test carried out on **biodiesel** sample submitted to it for analysis whether in tort or in contract, due to any act, omission or error of whatever nature, whether or not negligence and howsoever caused. Furthermore all expenses and implied warranties are specifically disclaimed.

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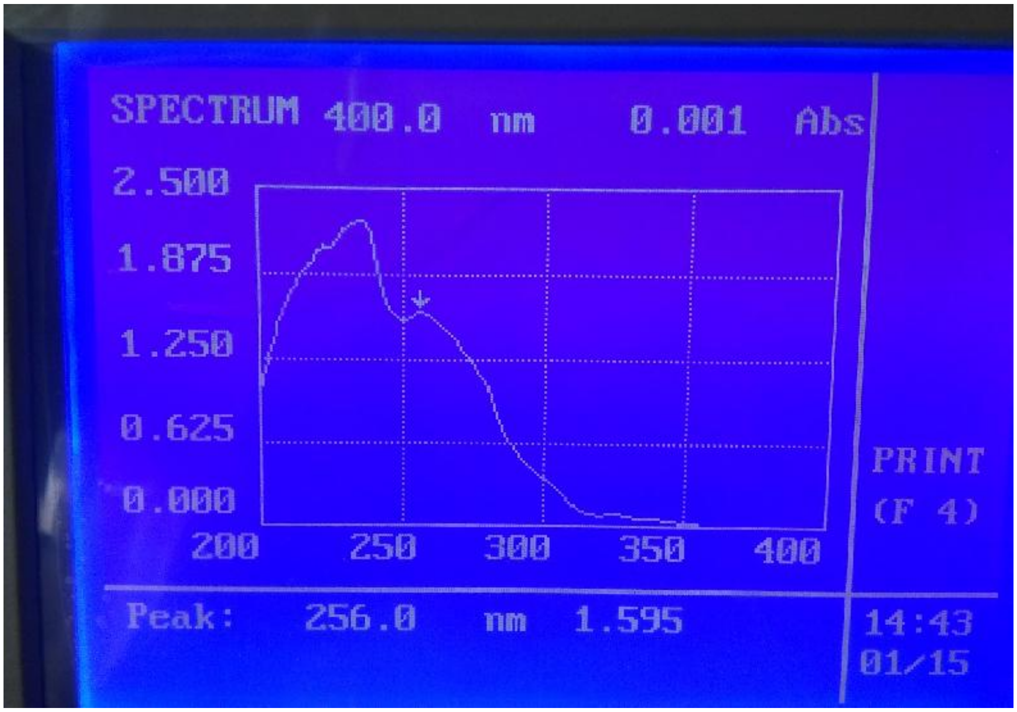
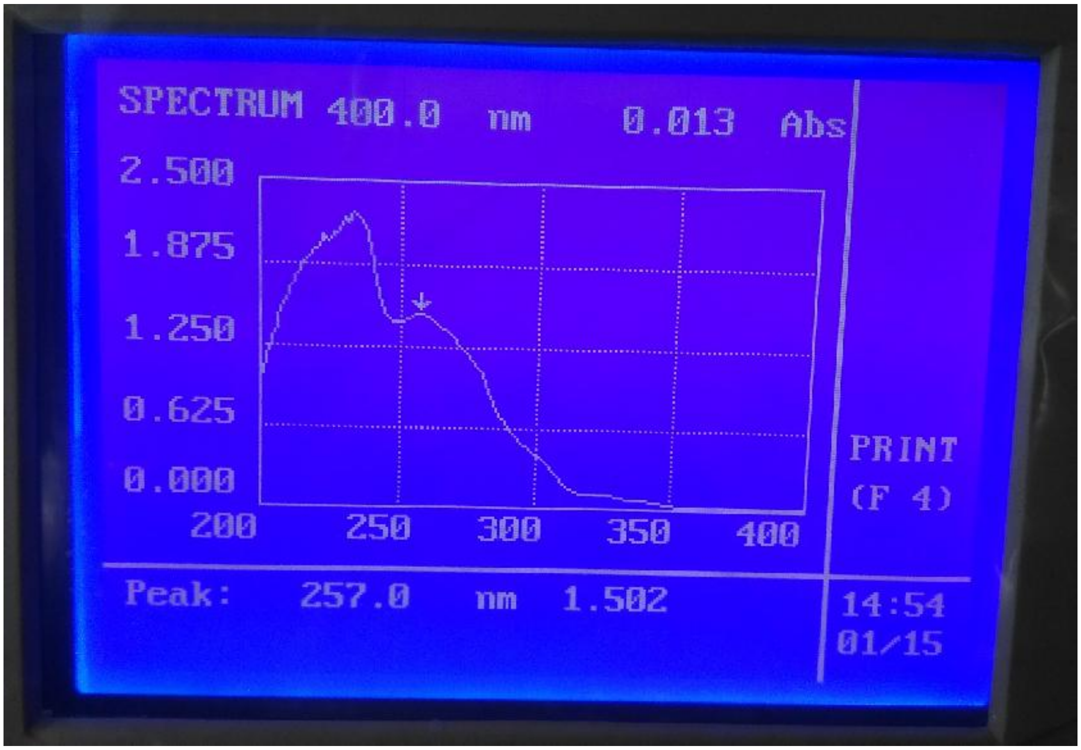
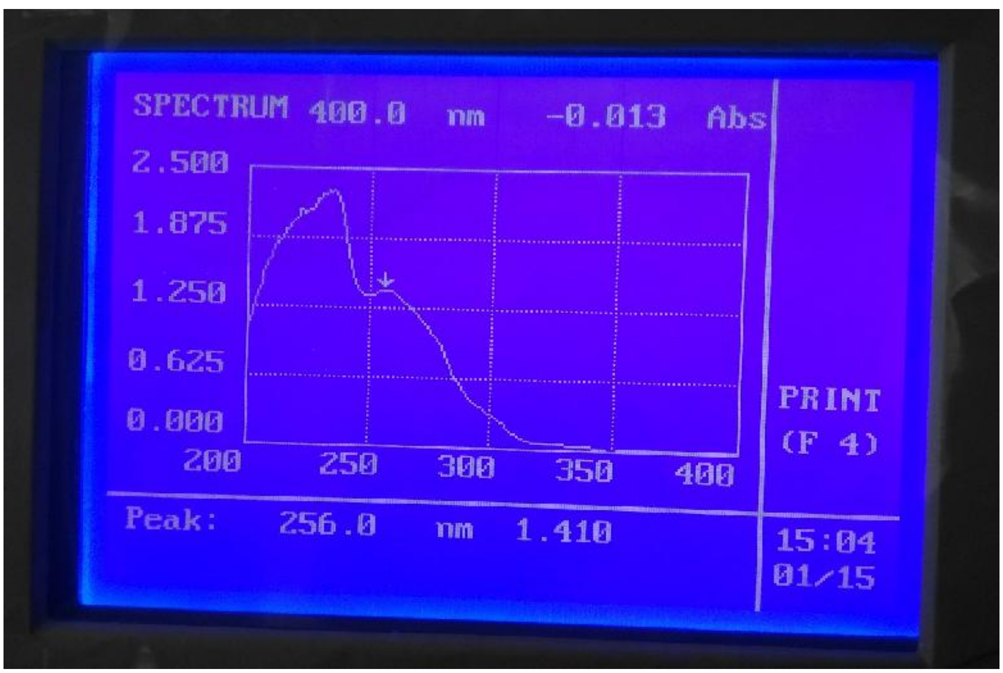


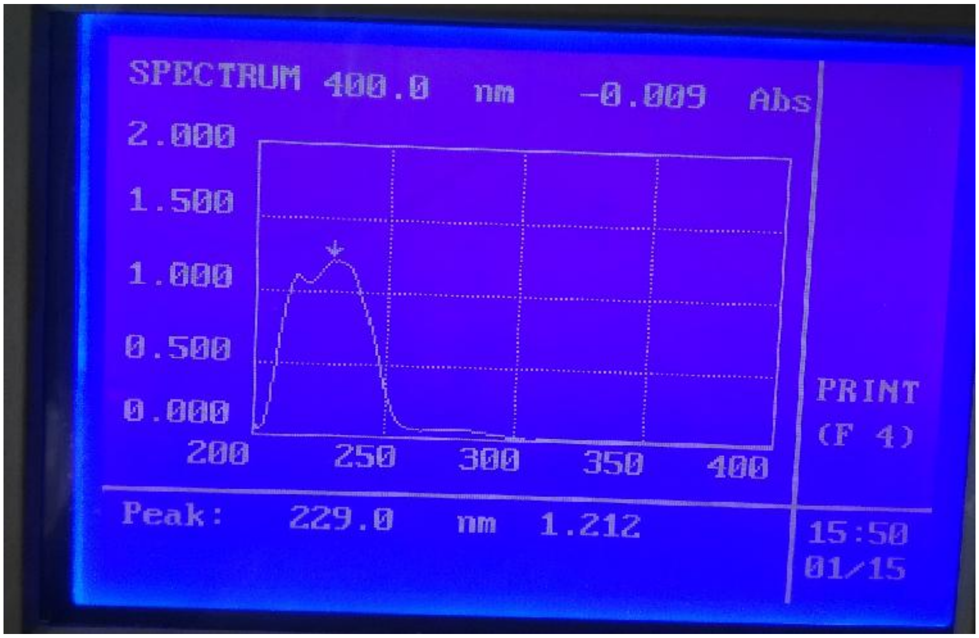
UV spectrum test result for B10



UV spectrum test result for B20



UV spectrum test result for B30



UV spectrum test result for B0.