ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

Performance Characteristics of Cotton Seed Biodiesel with Additive ethanol in Diesel Engine

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

By

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MECHANICAL SYSTEMS AND VEHICLE ENGINEERING PROGRAM

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Adama

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled "performance characteristics of cotton seed biodiesel with additive ethanol in diesel engine" in partial fulfillment of the requirements for the award of the degree of Master of Science in Automotive Engineering is an authentic record of my own work carried out from November , 2016 to September, 2017 under the supervision of N.Ramesh Babu, Associate Professor, Department of Mechanical and Vehicle Engineering, Adama Science and Technology University, Ethiopia.

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 candidate is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval**.**

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Advisor	**Signature**	**Date**

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ACRONYMS AND SYMBOLS

ADO	Automotive Diesel Oil
AOCS	American Oil Chemists' Society
a_r	axle ratio
ASTM	Standard Specification for Biodiesel Fuel
ASTU	Adama Science and Technology University
B_0	conventional diesel fuel
B_{10}	10% biodiesel and 90% diesel fuel
B_{100}	pure biodiesel fuel
B_{15}	15% biodiesel and 85% diesel fuel
B20	20% biodiesel and 80% diesel fuel
$B_{20}E_{10}$	B_{20} and 10% ethanol
$B_{20}E_{10}$+3%tween80	$B_{20}E_{10}$ plus 3% tween80
$B_{20}E_{15}$	B_{20} and 15% ethanol
$B_{20}E_{15}$+4.5%tween80	$B_{20}E_{15}$ plus 3% tween80
$B_{20}E_5$	B_{20} and 5% ethanol
$B_{20}E_5$+1.5%tween80	$B_{20}E_5$ plus 3% tween80
B_{40}	40% biodiesel and 60% petro diesel blend
B_5	5% biodiesel and 95% petro diesel blend
BSFC	Brake Specific Fuel Consumption
BTE	Brake Thermal Efficiency

℃	Temperature degree Celsius
CH_3OH	Methanol
CI	compression ignition
CO	carbon monoxide
CO_2	carbon dioxide
COME	cotton seed oil methyl ester
CP	Cloud point
CSA	Central Statistical Authority
DEE	diethyl-ether
DIN	Deutsches Institutes for Normung
DMC	dimethyl carbonate
DMC	dimethyl ether dimethyl carbonate
DME	dimethyl ether
EGR	exhaust gas recirculation
EN	European Standard
EPFL	Ecole-Polytechnic Federalè Luasensie
EPSE	Ethiopian Petroleum Supply Enterprise
EU	Europe
FAME	Methyl esters of fatty acids
FEF	fumigant energy fraction
FP	flash point

F_{tr}	Tractive force
GHG	Greenhouse gases
gm	gram
gm/ml	gram per millileter
gm/sec	gram per second
g_r	gear box ratio
H_2O	water
ha	hectare
HC	hydrocarbon
HOOCR	Free fatty acid
hr	hour
JB	jatropha biodiesel
JOME	jatropha oil methyl ester
JOME-DEE	jatropha oil methyl ester diethyl-ether
K	the calibration constant
Kg	kilogram
km/hr	kilometer per hour
KN	kilo newton
KOH	potassium hydroxide
KW	kilowatt
L	liter

LDL	Low density lipoproteins
mf	mass flow rate
ml	milliliter
ml/sec	milliliter per second
mm	millimeter
N	engine speed
N.m	newton meter
N/S	not specified
NaOH	sodium hydroxide
NaOOCR	Sodium soap
NCPA	National Cottonseed Products Association
NE	Nitroethane
NM	Nitromethane
NOx	Nitrogen
pb	Brake power
PM	parts per million
P_P	engine power
Pw	Wheel power
rpm	revolution per minute
r_w	wheel radius
sec	second

SFC	specific fuel consumption
t	time
Tb	Brake torque
TW	wheel torque
TWEEN80/TW80	Polysorbate 80
UHC	unburned hydrocarbon
USA	united states of America
$\tilde{V}$	Volume flow rate
V. S	vehicle speed
v/wt	Volume per weight
η_t	gear box efficiency
ρ	Density of the fuel

ABSTRACT

The focus of this thesis was pointed at exploring cottonseed biodiesel with ethanol additives in diesel engines. In this work, the methyl ester of cottonseed oil with additives was investigated for its performance as a diesel engine fuel. Fatty acid methyl ester was produced via transesterification process using potassium hydroxide as a catalyst and purified cottonseed oil which is extracted from the cotton seed was used.

The fuel samples were prepared by blending cotton seed biodiesel with ethanol, diesel and tween80 for best miscibility of ethanol with diesel. This blending was for B_{20} cottonseed biodiesel in the composition of $B_{20}E_5$+1.5%tween80, $B_{20}E_{10}$+3%Tween80 and $B_{20}E_{15}$+4.5%tween80 and pure diesel fuel was used for reference fuel. Moreover, after preparation of the tested fuels the kinematic viscosity, total acidity density and cloud point were measured and the measured results were changed. For instance, kinematic viscosity changes in percent were 35.3%, 37.5% and 38.7% for $B_{20}E_5$+1.5%Tween80, $B_{20}E_{10}$+3%Tween80 and $B_{20}E_{15}$+4.5%Tween80 respectively with reference to pure cottonseed biodiesel.

The performance parameters evaluated were torque, power and break specific fuel consumption. The results of experimental investigation of B_{20} cottonseed biodiesel with additives ethanol and reagent tween80 were compared with that of baseline diesel and methyl ester for characterization. The results indicate that the power, torque and break specific fuel consumption percentage variation of fuels with ethanol additives and the power torque decreases as the percentage of additive increases and the break specific fuel consumption increases with increasing amount of ethanol additive. The power and torque of conventional diesel fuel is higher than that of biodiesel blended B20 with additives and its break specific fuel consumption is lower. Furthermore, a diesel engine was operated successfully using ethyl ester of cottonseed oil and with additive of ethanol up to 15% as the soul fuel with acceptable performance.

Key words: Cotton seed biodiesel, Diesel engine, fuel blends, additive, ethanol, tween80, extraction, transesterification, performance

1. INTRODUCTION

1.1. Background of the study

Recently, EPFL engaged in development of a number of roadmap process in Ethiopia. Ethiopia imports petroleum for its fuel requirements, and the demand for petroleum fuel is rapidly increasing, which is associated with its growing economy and expanding infrastructure. Imported petroleum products account for the lion's share of the total import expenditure and absorb much of the total export earnings. The annual consumption of petroleum fuels amounts to more than 1.2 million tones which is equivalent to 5.4% of total final energy consumption. Imported petroleum products accounts about 40% of the total imports and absorbs 60% of export earnings [1]. On the other hand, the country has large amounts of arable land, labor force and a suitable climate for alternative fuels development. Alternative fuels development is therefore believed by the government to have the potential to meet a substantial proportion of the national energy need, reduce dependency on imported fossil fuels, create new business opportunities and contribute towards reducing Greenhouse Gas (GHG) emissions.

The government expressed a desire to work towards the development of sustainable alternative fuel, recognizing the potential for negative impacts - and was therefore interested in improving its regulatory framework. This in turn has led us to look for alternative fuels which are renewable, environmental friendly, sustainable availability and economically feasible sources of energy have emerged as a priority for research to resolve all these problems, which us ourselves can produce [2]. Among the alternatives being considered are methanol, ethanol, biogas and straight vegetable oils and biodiesels which are produced from vegetables oils, animal fats etc.,.

In order to ensure the country's continued development program, the national fuel security and environmental sustainability, it is important to increase fuel utilization and satisfy the demand partly by locally produced fuels such as biodiesel. "The Ethiopian biodiesel Development and Utilization Strategy" is targeted to supply fuels from locally produced biofuel (Jatropha, Castor bean, Palm oil sugar cane, and cotton seed, etc.) and the objective of the strategy is to ensure the production of biofuel without affecting food self-sufficiency, to improve balance of payment and to reduce environmental impacts [3].

Therefore, explorations to find biodiesel is the most promising alternative fuel to replace or 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, non-toxic, environmental friendly, and similar to diesel fuel [4].

The essential minimum requirements for biodiesel to be a more sustainable alternative for fossil fuels is that they should be produced from renewable raw materials and that their use has a low negative environmental impact and must be viable in economic and social terms.
In Ethiopia the gross available potential land for production of feedstock for biodiesel is estimated about 23.3 million hectares. Regionally, the available land in million ha is: Oromia 17.2, Benishangul Gumuz 3.1, Gambela 2.8, Somali 1.5, Amhara 1, Southern Nation Nationalities 0.05 and Tigray 0.007 [5]. Therefore cotton seed can be used as alternative for fossil fuel so as to meet biofuel requirement of the country.

This research, therefore, is intended to fill this gap by setting up a technical insight towards a small scale biodiesel production from cotton seed. Small scale production of biodiesel consists of oil extraction and processing of oil. Oil extraction from cotton seeds can be done by three different methods. These are mechanical extraction, solvent extraction and intermittent press extraction techniques. The selection of the extraction method will be subjected to availability, coast, quality, etc. The final step is processing the vegetable oil into diesel oil. In this process the oil will be transesterified using base catalysts like potassium hydroxide/sodium hydroxide and methanol/ethanol. After the transesterification process biodiesel fraction of the oil is then washed and dried.

Most of biodiesel productions in the world from different oil have been done using methanol alcohol. Although, methanol is expensive and, toxic relative to ethanol, greater conversions into biodiesel can be reached using methanol. Due to these reasons methanol is used for biodiesel production. Catalysts are the major raw material for production of biodiesel. A base catalyst such as sodium hydroxide and potassium hydroxide are commonly used. Therefore potassium hydroxide will be used for the production of the biodiesel; hence, this will help to produce biodiesel from cotton seed oil and potassium hydroxide.

Quality assessment of the biodiesel can be performed using cotton seed biodiesel and its blends of B_{20} & studying the effect of ethanol. TWEEN80 used for blending ethanol with diesel for mixing stability of ethanol. The samples used in this research were $B_{20}E_5$+1.5%TWEEN80, $B_{20}E_{10}$+3%TWEEN80 & $B_{20}E_{15}$+4.5%TWEEN80. The properties to be determined includes kinematic viscosity, density, flash point, cloud point, pour point, acid number and viscosity index were assessed. Then the performance test of the blends of cotton seed biodiesel with additive ethanol and pure diesel fuel were performed in the diesel vehicle.

1.2 Statement of the problem

Various researchers worked on cottonseed biodiesel with additive ethanol and were used as an alternative fuel in diesel engine. Cottonseed biodiesel has higher physicochemical properties than diesel engine. For optimum use of cottonseed biodiesel in diesel engine some properties must be improved using additive ethanol. Ethanol as additives plays a very important role in meeting the international fuel standards and real time problems which are associated with cottonseed biodiesel. With the help of ethanol additive the fuel properties can be enhanced and biodiesel in blend can be used with diesel in the vehicle. Ethanol additive can be one of the solutions using in cottonseed biodiesel. Therefore, it is a great necessity for developing inexpensive and good quality biodiesel and investigates the potential of adding ethanol to biodiesel blends and petro diesel blends.

1.3. Objectives of the study

1.3.1. General objective

The general objective of the study is to investigate/evaluate the performance of biodiesel produced from cotton seed with additive ethanol in diesel engine.

1.3.2. Specific objectives

- Investigate the potential of the cotton seed oil for biodiesel production
- To produce biodiesel from cotton seed oil by transesterification and characterize it.
- To blend biodiesel with diesel fuel and additive ethanol and characterize it.
- To test/conduct the performance of petro diesel and diesel-biodiesel blends of B_{20} with additive ethanol in diesel engine.

- To compare the performance of petro diesel and diesel-biodiesel blends of B_{20} with additive ethanol.

- To study the effect of ethanol on cotton seed biodiesel.

1.4. Significance of the study

Finding of this study offers knowledge and understanding of the performance of cotton seed biodiesel and petro diesel blends with ethanol as additive in a four stroke diesel engine.

This study should be significant in the sense of:

- Present the technology of biodiesel production technology.
- Show how to use different natural resources to produce biodiesel in small scale which will reduce our dependence on petroleum based fuels. Be used as base-line information for further studies particularly for small scale production of biodiesel from different vegetable oil sources that will meet international standards.
- Reduce the import of petroleum fuels.
- Optimize the performance of the engine using additive ethanol with biodiesel blended.
- It helps to protect the environment by lowering the greenhouse gas emissions.

It has environmental, energy security and economic benefits:

1. **Environmental Benefits**

Biodiesel contains no sulfur or aromatics, and use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matter. United States Department of Energy study showed that the production and use of biodiesel, compared to petroleum diesel, resulted in a 78.5% reduction in carbon dioxide emissions. Moreover, biodiesel has a positive energy balance. For every unit of energy needed to produce a gallon of biodiesel, 3.24 units of energy are gained.

It is an attractive alternative to petroleum diesel fuel due to well-known advantages, including the following:

- It provides the potential for lower dependence on petroleum crude oil
- It is a renewable resource
- It provides the potential for reduced greenhouse gas emissions because of the closed CO_2 cycle

- It has a lower combustion emission profile (especially SO_X)
- It provides the potential for enhancement of rural economies
- It is biodegradable
- It can be used without engine modifications
- It provides good engine performance
- Improved combustion is exhibited because of its oxygen content
- It exhibits low toxicity, and finally
- It has the ability to be blended in any proportion with regular petroleum-based diesel fuel
- It can also be used in boilers or furnaces designed to use heating oil's or in oil-fueled lighting equipment.

2. **Energy Security Benefits**

With agricultural commodity prices approaching record lows, and petroleum prices approaching record highs, it is clear that more can be done to utilize domestic surpluses of vegetable oils while enhancing energy security. Because biodiesel can be produced using existing industrial production capacity, and used with conventional equipment, it provides substantial opportunity for immediately addressing our energy security issues.

3. **Economic Benefits**

Increased utilization of renewable biofuels results in significant microeconomic benefits to both the urban and rural sectors, and the balance of trade. In addition to being a domestically produced, renewable alternative fuel for diesel engines, biodiesel has positive performance attributes such as increased cetane, high fuel lubricity, and high oxygen content, which may make it a preferred blending stock with future ultra-clean diesel.

1.5. Scope of the study

- This scope of this study is to investigate the contribution of ethanol on biodiesel produced from cotton seed in diesel engines and to test performance characteristics of biodiesel with comparison of petro diesel. In this study, the analysis focused on investigation of the performance of cotton methyl ester with additive ethanol in diesel engine and testing the blend with additive ethanol in diesel engine. Comparing the results and characterize the property of the fuel.

1.6. Limitation of the study

The performance test was conducted using Chassis dynamometer which only used to measure the tractive effort and wheel power. Because the engine dynamometer was not work which was used to measure brake power and torque directly from engine.

Due to shortage of budget:

- The complete characterization of biodiesel and its blends were not done.
- This test is not covered the other test samples; it only focused on B_{20} with additives and its performance.

In addition to this, it was also difficult to find researches that have been done nationally and lack of reference books.

1.7. Organization of thesis

This thesis organized into five chapters as follows.

The first chapter covers the introduction: background, Statement of the problem, Objective of the study, Significance of the study, scope of the study and limitation of the study.

The second chapter reviews the following related literatures: overall of cotton seed plant, biodiesel and its sources, cotton seed possible extraction techniques, transesterification process, blending process and its need on performance fuel additives, reagents tween80, biodiesel fuel quality lubrication properties & engine performance.

The third chapter presents the materials and methodology used in this thesis. This includes the materials & methodology of the research used, production of cotton seed oil, determination of crude cotton oil content, transesterification of cotton seed oil, production of biodiesel layout, characterization of cotton seed biodiesel, experimental facilities for the test and ASTM standard test methods.

The fourth Chapter presents the result and discussion of: This includes oil content from extraction, Production of biodiesel and vehicle performance test.

The final chapter presents the conclusion and recommendation of this thesis based on the results obtained.

2. LITERATURE REVIEW

2.1. Introduction

The world is presently confronted with the twin crises of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based carbon resources. The search for alternative fuels, which promise a harmonious correlation with sustainable development, energy conservation, efficiency and environmental preservation, has become highly pronounced in the present context. The fuels of bio origin can provide a feasible solution to this worldwide petroleum crisis. Gasoline and diesel-driven automobiles are the major sources of greenhouse gases (GHG) emission [6–8]. Scientists around the world have explored several alternative energy resources, which have the potential to quench the ever-increasing energy thirst of today's population. Various biofuels energy resources explored includes biomass, biogas, primary alcohols, vegetable oils, animal fats, biodiesel, etc. [9]. These alternative energy resources are largely environment-friendly but they need to be evaluated on case-to-case basis for their advantages, disadvantages and specific applications. Some of these fuels can be used directly while others need to be formulated to bring the relevant properties closer to conventional fuels.

Due to the recent widespread use of petroleum fuels in various sectors, this study concentrates on assessing the viability of using alternative fuels from cotton seed with the addition of ethanol as additive in the existing internal combustion engines.

The present energy scenario has stimulated active research interest in non-petroleum, renewable, and nonpolluting fuels. The world reserves of primary energy and raw materials are, obviously, limited. According to an estimate, the reserves will last for 218 years for coal, 41 years for oil, and 63 years for natural gas, under a business-as-usual scenario [10, 11]. The enormous growth of world population, increased technical development, and standard of living in the industrial nations has led to this intricate situation in the field of energy supply and demand. The prices of crude oil keep rising and fluctuating on a daily basis. The crude- oil prices are at near record levels and are stabilizing at about US$120 per barrel now. This necessitates developing and commercializing fossil fuel alternatives from bio-origin. 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 oils and animal fats) by transesterification with methanol, present the promising alternative substitute to diesel fuels and have received the most attention now a day. 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 [9].

2.2. Cotton plant and production

Cotton is a soft, warm-weather shrub or tree, fluffy staple fiber that grows in a boll, or protective case, around the seeds of the cotton plants of the genus Gossypium in the mallow family Malvaceae. Cotton is 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 product of cotton crop. Now, cotton seed oil is also widely used for human consumption. Thus, cotton has become a fiber cum oil yielding crop. Its seeds also contain 20-25% protein. Hence, in future, cotton will become a source of fiber; oil and protein. There are four products of cotton plant viz.lint, seed, stalk and leaves. Out of these, lint is the main product and rest is by-products [12]. The fiber is almost pure cellulose. Under natural conditions, the cotton bolls will increase the dispersal of the seeds. Cotton is primarily cultivated for its lint or fiber, in other words, lint is the main products of cotton crop. Cottonseed contains hull and kernel. The hull produces fiber and linters. The kernel contains oil, protein, carbohydrate and other constituents such as vitamins, minerals, lecithin, sterols etc. Cottonseed oil is extracted from cottonseed kernel. Cottonseed oil, also termed as "Heart Oil" is among the most unsaturated edible oils. It need not be as fully hydrogenated for many a cooking purposes as is required in case of some of the more polyunsaturated oils. Cottonseed oil is a popular vegetable oil extracted from the seeds of cotton plants of various species, mainly Gossypium hirsutum and Gossypium herbaceum that are grown for cotton fiber, animal feed, and oil [13]. This oil is inexpensive and has a longer shelf life than most cooking oils. Cotton seed has a similar structure to other oilseeds such as sunflower seed, having an oil-bearing kernel surrounded by a hard outer hull; in processing, the oil is extracted from the kernel. Cottonseed oil

is used for salad oil, mayonnaise, salad dressing, and similar products because of its flavor stability [14].

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

Fig.2.1. cotton plant production

The origin of cotton is disputed. Cotton is a native plant to Mexico and India. Cultivation of cotton happened around 5000 years ago in these two places. It was slow to spread throughout the world [15, 16].

The plant is a shrub native to tropical and subtropical regions around the world, including the Americas, Africa, and India. The greatest diversity of wild cotton species is found in Mexico, followed by Australia and Africa [16]. Cotton was independently domesticated in the Old and New Worlds.

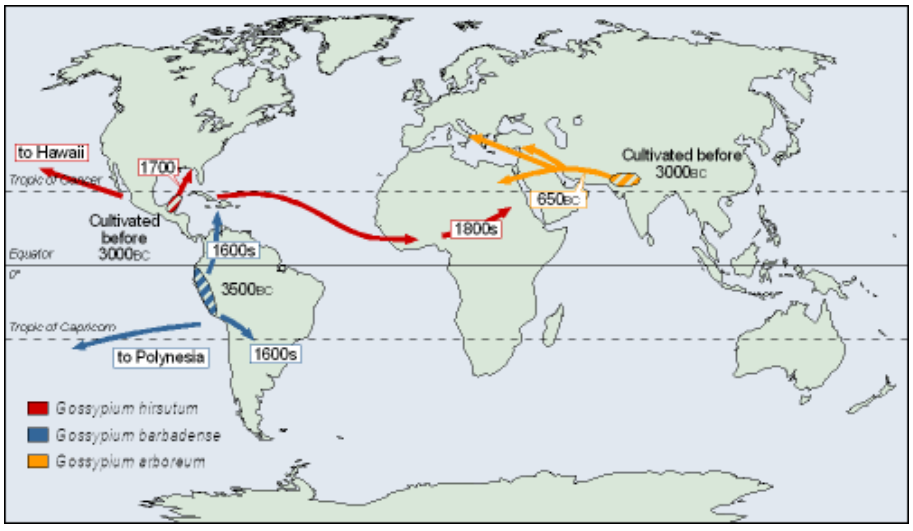

Fig.2.2.Origin of cotton plant

2.3. Cotton production in Ethiopia

Ethiopia is believed to be one of the origins of cotton, and cotton cultivation is deep-rooted in the history of the country's agriculture. Cotton is one of the major cash crops in Ethiopia and is extensively grown in the lowlands under large-scale irrigation schemes. It is also grown on small-scale farms under rain-fed agriculture [17].

Ethiopia annually produces approximately 120,000 tons of cotton (Central statistics Agency). Much of the cotton production in Ethiopia is from small-scale farmers, who cultivate about 39,600 hectares annually. The total area under cotton plantation by the private owned enterprises is 54,000 hectares.

According to the Report on large and Medium Scale Manufacturing and Electricity Survey (2002) of the Central Statistical Authority (CSA) The country produces cotton both for the local and export markets. In 2007/08, the country's textile industries used 52,936 tons of locally produced cotton as raw material. In the same year, export of cotton from the Country was 14,360 tons valued at US$ 19 million.

Cotton is basically a crop of warmer climates. In Ethiopia, a good cotton yield is obtainable from areas varying in altitude from sea level to about 1000m. The country's potential areas of cotton growing are such as Omo-Ghibe, Wabi-Shebele, Awash, Baro-Akobo, 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 269130ha, in Amhara 678,710 ha, in SNNPR 600,900 ha, in Oromia 407420 ha, Gambella 316,450, Benshangul 303,170ha, Afar 200,000 ha and Somali 225,000ha. Most of the areas are low land and at river basins.

The leading cotton-growing countries are Egypt, Tanzania, Chad, Mali, Benin, Burkina Faso etc. Ethiopia's share is total cotton produced in Africa is about 5%. Africa had to face continuous difficulty in exporting cotton since USA exports cotton with high subsidy. Cotton cultivation cost is lower in Africa as compared to other countries. However, in the absence of good domestic demand and their inability to adopt cotton, the yield per hectare is low. With the current global scenario where food has received priority over other crops, land surplus countries like Ethiopia clearly have an advantage in adopting cotton cultivation [17].

Ethiopia has a long tradition of cotton cultivation. Ethiopia currently cultivates 3% of the total 2.6 million hectares that is suitable for cotton production. The current annual production of seed cotton is approximately 120,000 tons with an overall yield of 1.42 ton/hectare. The total

production of lint cotton in Ethiopia is around 42,000 tones out of which about 32,000 tones is consumed by domestic textile industry. Majority of the cotton cultivation takes place in the Awash Valley, with some cultivation also taking place in Gambela, Humera, and Metema. The cotton farming cycle varies from area to area. Cotton is planted earliest (by mid-April) in the case of Middle Awash, while in Lower Awash planting of cotton takes place in late June. Harvesting of cotton shows less time variation .Of the total land under cotton cultivation, 33% is cultivated by small holders, 45% by private farms and 22% are state owned farms [17].

Ethiopia produces primarily long staple cotton, with staple length of around 30 mm. There are four varieties of cotton that are usually cultivated in Ethiopia. These are:-

- ✓ Mid awash
- ✓ Basen
- ✓ Hiwot
- ✓ Samen omo

Ethiopia has excellent cotton-growing conditions and a significant amount of land potentially suitable for cotton production.

If Ethiopia has to eradicate poverty and meet its human development goals, then it has to sustain an 8% to 10% economic growth rate, over the next 25years. For delivering a sustained growth rate of 8%, Ethiopia needs to increase its primary energy supply by 3 to 4 times. New sources of energy like cotton biodiesel ethanol may play a significant role in meeting the energy demands. Biodiesel sources have turned out to be more effective in the recent days because of the insufficiency of conventional fossil fuels, their price hike and increased emissions of pollutants generated during combustion. Therefore biodiesel which produced from cotton seed cultivated in Ethiopia can be the solution.

2.4. Composition of cotton seed oil

Cottonseed oil is cholesterol free, as are all oils extracted from plants. Linoleic acid is the major polyunsaturated fatty acid found in cottonseed oil. Its fatty acid profile generally consists of 70% unsaturated fatty acids (18% monounsaturated, and 52% polyunsaturated), 26% saturated fatty acids. The contents of cotton seed oil are as follows. Linoleic acid: 49% t0 58%, oleic acid: 15% to 20%, palmitic acid: 22% to 26%, behenic acid and lignoceric acid/arachidic acid: 10%.

2.5. Benefits & Uses of Cottonseed Oil

There are numerous benefits of cottonseed oil, such as its ability to lower cholesterol, protect the skin, improve the immune system, reduce inflammation, speed healing, boost cognition and even prevent certain types of cancer. However, cottonseed oil also comes along with various side effects, such as potential risks to heart health, increased risk of certain cancers and fertility problems. Many of these are due to low quality or highly processed cottonseed oil, so users must be cautious regarding the source and composition of their cottonseed oil [18].

2.6. Cottonseed Oil Dangers

Cottonseed oil is a cooking oil that is extracted from the cotton plant. Though there are benefits, a few negative effects can also be found.

Even though cottonseed oil is a popular 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 [19].

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. This toxin is used as a component in male contraceptives in China. It can cause a series of reactions in men who suffer from a deficiency of potassium. 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 [20].

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.

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.

Genetic modification

In order to extract oil from cottonseed, these seeds have to be modified genetically. The cotton plants are crossbred with super weeds that are a wild species of weeds. This crossbreed of cotton plants is resistant to infestation of weevils and other insects. These plants also require dangerous herbicides that may be hazardous for human consumption. These herbicides reverse the effect of antibiotics and make diseases such as tuberculosis and sexually transmitted diseases including gonorrhea difficult to treat.

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 make an individual more prone to different types of cancer.

While the National Cottonseed Products Association (NCPA) does not mention any of the aforementioned dangers of cottonseed oil, there are many renowned health experts who suggest that this is the oil that should not be in your diet. One such health expert is Dr. Andrew Weil, M.D., who says, "... One of the first things I ask readers to do is to go through their pantry shelves and throw out anything made with cottonseed oil." The main threatening factors in this oil are: The fact that heavy degrees of pesticides are used while crop growth and that most of the production are derived from genetically modified seeds. These days, many manufacturers have come up with a "healthier" version of this disputed product, claiming that their oil is free from pesticide and is heart-healthy. Unless, you are sure of the oil (and the extraction source) being free from pesticide exposure and genetic alterations, it would be best to refrain from it.

Ultimately, your decision will be based on your individual evaluation of the pros and cons of this subject [21].

2.7. Cotton seed oil extraction methods

There are two main types of processes for obtaining oil. These are physical and chemical processes. The physical process/extraction involves the use of mechanical power to remove oil from the seed which includes 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 screw presses).

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. At the beginning of the twentieth century the vegetable oil industry worked basically with the hydraulic presses but even making use of a hydraulic cylinder, work with this type of equipment was considered labor intensive. With the emergence of the continuous screw press, the only application that still requires the hydraulic press is the one that requires gentle handling, such as processing and production of the oil. Presses from this category can be divided into two main groups: open and closed type [22].

Open-type presses: the fresh material, previously prepared and wrapped in press-cloths, is placed between the plates that should be corrugated to assist drainage and overcome cake creepage. In a standard process, it takes 2 minutes to feed the press, 6 minutes to reach maximum pressure, 20 minutes to drain and 2 minutes to remove solids, a total of 30minutes per batch.

Closed-type presses: in this type, the oilseed is enclosed by a strong perforated steel cage that can apply much more pressure than an open press. Removing oil from the interior of the grain is attained by the pressure applied by a piston placed close to the cage and hydraulically operated. Oil flows through channels that increase in size from inside to outside the cage, thus avoiding any clogging with solid particles [22].

2.7.2. Continuous mechanical pressing screw presses)

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.

The operating principle of this equipment consists a helical screw which moves the material, compressing it, and at the same time, eliminating the oil and producing the cake. Optimization of the continuous mechanical pressing consist of defining the optimum parameters, such as temperature and moisture content of grain, or adjustments on the press, in order to reach optimum yields of oil, using a minimum value of pressure applied by the press**.**

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 [22].

One of the disadvantages of the extraction is that the solvent extracts some non-triglycerides, which does not occur in the expelling [22]. Another serious problem is the presence of volatile organic impurities in the final product, which can compromise the quality and go against the new profile of consumers who are seeking for natural products aiming to have a healthier diet [23].

The process known as pre-press is designed to prepare the high oil content raw material to the solvent extraction. Mechanical pressing reduces the oil by half to two thirds of its original level facilitating solvent extraction by reducing the amount of oil to be extracted, the size of extractor equipment and also the volume of solvent used [24].

The principle of the method is to perform successive washing of oleaginous material with solvent until equilibrium is reached or near equilibrium between the oil content of the solid and that of the solvent, i.e., when the solvent absorbed by the solid and solvent in the free miscella

containing the same amount of oil dissolved. When this occurs, the miscella is drained and another washing takes place.

The choice of solvent takes into account a number of factors, notably, solvent extraction capacity, effects of solvent on oil properties, process safety, solvent volatility and stability, and economic considerations.

In 1947, it was published a study evaluating the various types of solvents such as benzene, aviation gasoline, methanol, ethanol, isopropanol, carbon disulfide, diethyl ether, ethylene dichloride, carbon tetrachloride, trichloroethylene and the various petroleum naphtha's. However, in 1947, the most commonly used solvents in the United States were light paraffinic petroleum fractions, such as the hexanes, heptanes and pentanes. The hexane was finally chosen because of its ease to evaporate and left no residual obnoxious odors or tastes. There are two types of hexane: normal, also known as n-hexane; and commercial, named extraction-grade hexane. The n-hexane is pure and boils at 69℃, while the extraction-grade hexane is not pure. The Clean Air Act of 1990 (public law) considered hexane as one of 189 hazardous air pollutants, encouraging research to seek alternative solvents for the extraction of oil. Examples of alternative solvents studied are halogenated solvents, water as a solvent, enzyme-assisted aqueous extraction, acetone as a solvent, alcohols as solvents and supercritical solvents.

The ability to extract oil from an oilseed depends on the nature of the oil, the nature of the solvent, the temperature and the contact time between solvent and grain mass, flake thickness and conditions of pretreatment of the seeds. Attah & Ibemesi (1990) evaluated the solvent capacity and solvent effects in the extraction of oils from four native plants. The following solvents were used: petroleum benzene (60-80℃), cyclohexane, isopropyl ether, ethyl acetate, tetra-hydro-furan, propan-2-ol and acetone. The authors found that oil extraction performance of each solvent appears to be generally dependent on the nature of the oil, i.e. ethyl acetate and tetra-hydro-furan gave the highest oil yields in rubber, their oil yields in melon gave next to lowest value. Another important consideration was that solvent did not affect the increase in the level of free fatty acid of extracted oils [25]

2.8. Biodiesel production and process

It is well known that viscosity is the main barrier that prevents the use of direct vegetable oils in conventional diesel engines. Therefore, there are many techniques, methods and processes that have been used recently to produce biodiesel from various non-edible feed stocks. These

methods include; pyrolysis, micro-emulsification, dilution, and transesterification [26, 27]. The flow chart shown in Fig. 2.3 describes the route to produce biodiesel from non-edible oil seeds [28].

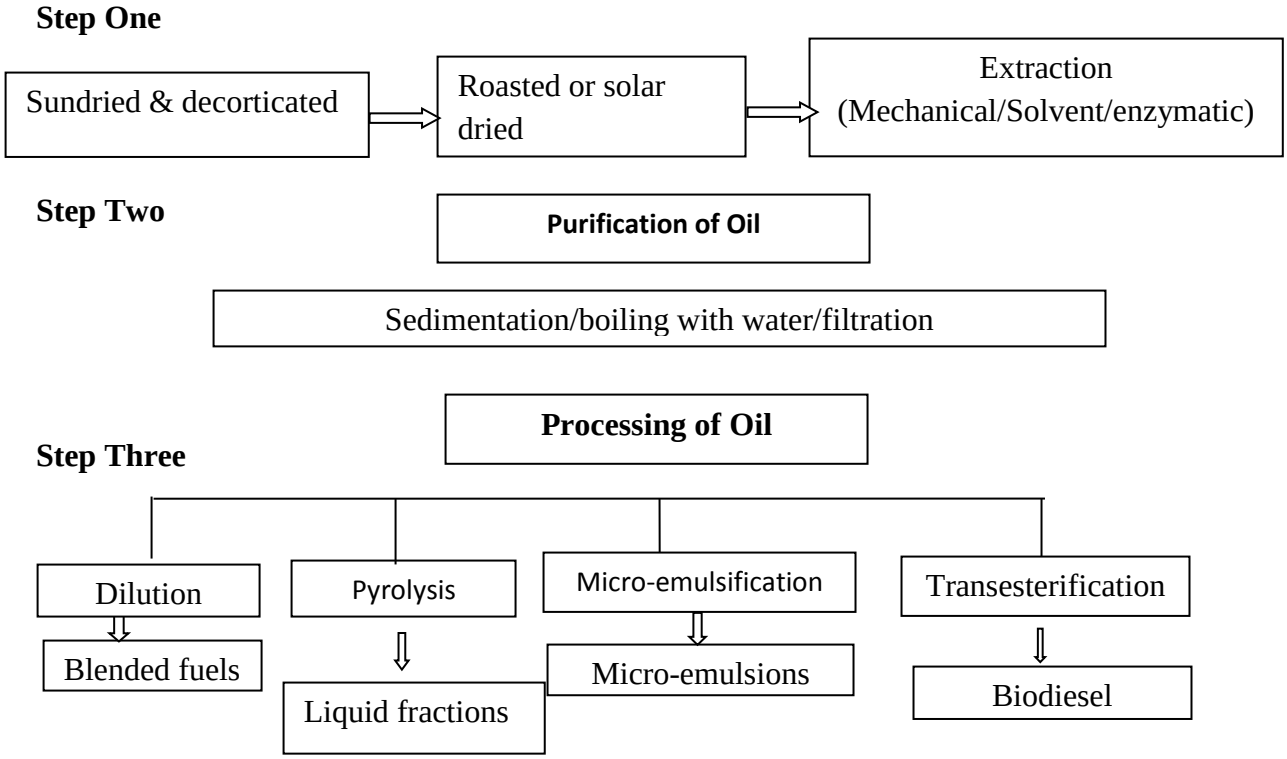

Figure.2.3. Process flowchart of non-edible crops seed to biodiesel

2.8.1. Pyrolysis (Thermal cracking)

Pyrolysis is the thermal conversion of the organic matters in the absence of oxygen and in presence of a catalyst. The paralyzed material can be vegetable oils, animal fats, natural fatty acids or methyl esters of fatty acids. Thermal decomposition of triglycerides produces alkanes, alkenes, alkadines, aromatics and carboxylic acids. The liquid fractions of the thermally decomposed vegetable oils are likely to approach diesel fuels. The pyrolyzate had lower viscosity, flash point, and pour point than diesel fuel and equivalent calorific values. However, cetane number of the pyrolyzate was lower compared to diesel fuel. The pyrolyzed vegetable oils contain acceptable amounts of sulfur, water content, copper corrosion values and sediments but unacceptable ash, carbon residual and pour point [29, 30].

2.8.2. Micro emulsification

Micro emulsification is defined as transparent, equilibrium thermodynamically stable colloidal dispersion of microstructure with diameter ranges from 100 to 1000 A˚. Micro emulsion can be made of vegetable oils with an ester and dispersant (co solvent), or of vegetable oils, and alcohol such as ethanol, methanol, buthanol, hexanol and a surfactant and a cetane improver, with or without diesel fuels. Micro emulsification has been considered as a reliable approach to solve the problem of the high viscosity of vegetable oils [29, 30 and 31].

2.8.3. Dilution

Non-edible oil can be diluted with diesel to reduce the viscosity and improve the performance of the engine. This method does not require any chemical process [32, 33]. It has been reported that substitution of 100% vegetable oil for diesel fuel is not practical. Therefore, blending of 20–25% vegetable oil to diesel has been considered to give good results for diesel engine [26, 32].

2.8.4. Transesterification (Alcoholysis)

One of the most promising processes to convert vegetable oil into methyl ester (biodiesel) is the transesterification, in which alcohol reacts with tri-glycerides of fatty acids (vegetable oil) in the presence of catalyst [34].

Transesterification or alcoholysis is defined as the chemical reaction of alcohol with vegetable oils. In this reaction, methanol and ethanol are the most commonly used alcohols because of their low cost and availability. This reaction has been widely used to reduce the viscosity of vegetable oil and conversion of the triglycerides into ester. The transesterification reaction is shown in below.

$$\begin{array}{l} CH_2-COOR_1 \\ CH-COOR_2 \\ CH_2-COOR_3 \end{array} + 3CH_3OH \rightleftharpoons \begin{array}{l} CH_2-OH + R_1COOCH_3 \\ CH-OH + R_2COOCH_3 \\ CH_2-OH + R_3COOCH_3 \end{array} \quad (1)$$

Vegetable oil alcohol glycerol methyl-ester

Fig.2.4.Transesterification reaction of triglycerides

Transesterification can be carried out by two ways: catalytic transesterification and Non-catalytic transesterification [35]. Juan et al. [36] reviewed biodiesel production from Jatropha oil using catalytic and non-catalytic approaches.

It is widely known that catalytic transesterification is confronted with two problems. The main problem is the processes are relatively time consuming and needs separation of the vegetable oil/alcohol/catalyst/saponified impurities mixture from the biodiesel. Furthermore, the waste water generated during biodiesel purification is not environment friendly. Under such condition, the supercritical alcohol transesterification is one result, the reaction was found to be complete in a very short time. Moreover, purification of biodiesel is much easier as no catalyst is required during supercritical transesterification process, thus preventing soap formation or saponification to occur. However, the drawbacks of supercritical alcohol transesterification process are due to the high temperature and pressure that result in the high cost of the apparatus. Many researchers have been working on non-edible biodiesel production from various feedstocks under different conditions using supercritical alcohol transesterification.

2.8.5. Variables Affecting Alkali Catalyzed Transesterification Reaction

Transesterification reaction process is influenced by a variety of working factors. These are molar ratio of alcohol to oil, amount and catalyst type, reaction time, reaction temperature, stirring rate, presence of free fatty acids and moisture [37].

2.8.5.1. Stirring rate

Oils and alcohols are not totally miscible, thus reaction can only occur in the interfacial region between the liquids and transesterification reaction is a moderately slow process; for this reason dynamic mixing is required to increase the area of contact between the two immiscible phases. Alcoholysis process can be enhanced by the agitation intensity of the reactor. Mass transfer of biodiesel from the oil phase towards the alcohol-oil interface might be a vital step that limits rate of alcoholysis reaction because the reaction is heterogeneous mixture. Reduced mass transfer between two phases in the initial phase of the reaction results in a sluggish reaction rate, the reaction being mass transfer controlled. Fast stirring accelerates transesterification reaction; therefore, variations in mixing strength are expected to change the kinetics of the transesterification reaction [37, 38].

2.8.5.2. Molar ratio of alcohol to oil

One of the most important parameters affecting the yield of biodiesel is the molar ratio of alcohol to triglyceride. Stoichiometrically 3 moles of alcohol and 1 mole of triglyceride are required for transesterification to yield 3 moles of fatty acid methyl/ethyl esters and 1 mole of glycerol is

used. Transesterification is an equilibrium controlled reaction in which excess of alcohol can be used to get complete conversion and alcohol is easily recoverable. Further, the conversion efficiency is remains the same, but to decrease the energy increment required for the recovery of alcohol, we should avoid increasing molar ratio of alcohol to oil. Additionally, excessive amount of alcohol makes the recovery of the glycerol difficult, since more excess alcohol hinders the decantation by gravity so that the apparent yield of esters decreases since part of the glycerol remains in the biodiesel phase. The molar ratio is associated with the type of catalyst used such as; alkali catalyzed transesterification reaction the alcohol to oil molar ratio is about 6:1 to 12:1 which are the most acceptable for maximum conversion to esters. When using acid catalyst instead of alkali catalyst, the desirable maximum conversion is obtained with sulfuric acid with alcohol to oil molar ratio of 30:1 [38, 39, and 40]. The molar ratio of alcohol to oil has no effect on acid value, saponification values and iodine values of esters [41].

2.8.5.3. Free fatty acid and moisture content

The free fatty acid and moisture content are the key parameters for determining the viability of vegetable oils to be used in transesterification process. Presence of moisture content in the oil increases the amount of free fatty acids. To carry out this reaction to completion, less than 3% free fatty acid content in oils is needed [42]. Higher the acidity of the oil, smaller is the conversion efficiency. Free fatty acids react with the basic catalyst added for the reaction and give rise to soap, as a result of which, one part of the catalyst is neutralized and is therefore no longer available for transesterification. High free fatty acid content oils are processed with an immiscible basic glycerol phase so as to neutralize the free fatty acids and cause them to pass over the glycerol phase. The starting materials used for base catalyzed alcoholysis should meet certain specifications. The triglycerides should have lower acid value and all material should be substantially anhydrous. The addition of more sodium hydroxide catalyst compensates for higher acidity, but the resulting soap causes formation of gels that interferes in the reaction as well as with separation of glycerol [43, 37, and 42].

The presence of alkali catalyst and free fatty acid results to the formation of soap which is undesirable because the soap attaches the catalyst and making the catalyst inactive to accelerate the reaction. Additionally disproportionate soap in the products can restrain later in processing of

the biodiesel, glycerol separation and water washing. The reaction of free fatty acid and alkali catalyst is shown below.

$$HOOCR + NaOH \rightarrow NaOOCR + H2O \quad (2)$$

Free fatty acid sodium hydroxide sodium soap water

So as to reduce the formation of soap as side reaction the oil as raw material should meet certain specifications when base catalyzed alcoholysis is used. Triglycerides ought to have lower acid value and all material should be substantially water free. Higher acidity can be avoided by adding more sodium hydroxide catalyst; however formed soap results in the formation of gels that hinders the reaction as well as with glycerol separation.

2.8.5.4. Alkali catalyst amount

A catalyst is needed to improve the transesterification reaction and amount of yield production. The alkaline catalysts such as sodium hydroxide and potassium hydroxide are most widely used. These catalysts increase the reaction rate several times faster than acid catalysts. Alkaline catalyst concentration in the range of 0.5 to 1.125% by weight yields 94 to 99% conversion efficiency. Further increase in catalyst concentration does not increase the yield, but it adds to the cost and makes the separation process more complicated [44].

2.8.5.5. Reaction time and temperature

The rate of the transesterification reaction is strongly influenced by the reaction temperature. Generally, the reaction is carried out close to the boiling point of ethanol (70-75°C) at atmospheric pressure.

With further increase in temperature there is more chance of loss of ethanol. When the reaction temperature exceeds the boiling point of alcohol, the alcohol will vaporize and form a large number of bubbles which may inhibit the reaction. The completion of the basic catalyzed transesterification process depends on reaction time. The transesterification reaction is commonly conducted close to the boiling point of the alcohol at atmospheric pressure for one hour [45]. Excess reaction time does not increase the conversion but favors the backward reaction (hydrolysis of esters) which results in a reduction of product yield.

2.8.6. The base catalyzed production of biodiesel

The base catalyzed production of biodiesel generally has the following process steps [46].

2.8.6.1. Mixing of alcohol and catalyst

This typical process is mainly done by mixing alkali hydroxide (commonly potassium hydroxide and sodium hydroxide) with common alcohols (methanol and ethanol) in the mixer with standard agitator to facilitate the mixing. Alkali hydroxide is dissolved in the alcohol to produce alkoxide solution. The alcohol and catalyst used were methanol & potassium hydroxide respectively.

2.8.6.2. Chemical reaction

The alcohol and catalyst mixture is then charged into a closed reaction vessel and the oil is added. The reaction system is totally closed to the atmosphere to prevent the loss of alcohol, since it easily vaporizable. Aluminum foil was used for closing. The reaction mixture is kept just near the boiling point of the alcohol to speed up the reaction. Excess alcohol is normally used to ensure total conversion of the oil to its esters as there is no problem of recovering of the alcohol for later use after recycling.

2.8.6.3. Separation

After the reaction is completed, there exists glycerol and biodiesel formation. Both have a significant amount of the excess alcohol that was used in the reaction which is in need of being recovered. The reacted mixture is sometimes neutralized at this step if the basic media that is caused by alkali hydroxide is occurred. The glycerol phase is much denser than biodiesel phase, making biodiesel to be floated.

The two products can be separated by gravity using settling vessel/separator funnel. The glycerol is drawn off at the bottom of the settling vessel/ separatory funnel and biodiesel is drawn off at the top. In some cases, a centrifuge is used to separate the two materials faster by screening both phases.

2.8.6.4. Alcohol removal

After the glycerol and biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation commonly. But currently extractive distillation can instead be used to fasten the process and to be more economical. On the other hand, the alcohol is removed and the mixture neutralized before the glycerol and esters have

been separated to prevent the effect of basic media inside the reactor. After the alcohol is being recovered it is used as main raw material.

2.8.6.5. Biodiesel washing

After the Biodiesel is separated from the glycerol, it is sometimes purified by washing gently with distilled warm water to remove residual catalyst, alcohol or soaps to make more pure. The washed biodiesel needs drying in order to remove trace impurities. In some processes washing step is not necessary depending on the quality of biodiesel produced.

2.9. Catalyst

In recent years, various catalysts (homogenous, heterogeneous, and enzyme catalyst) had been tested for the production of alkyl esters. Vicente et al. [47] studied using various base catalysts for production of alkyl esters and concluded that NaOH is the fastest catalysts among the catalysts used (NaOH, KOH, sodium methoxide, the potassium methoxide). Refaat et al. [48] reported that KOH gives the highest yield for feedstock he had used. Some of the researchers used concentrated sulfuric acid as acid catalyst [49, 50], but it requires high reaction time and high reaction condition. Even 1% (mole) can give up to 99% conversion [51]. In the case of raw material having higher free fatty acid content, acid catalyst (homogenous/heterogeneous) are used for esterification reaction [52]. Acid catalyst can be used simultaneously for both esterification and transesterification reactions [53]. One of the main disadvantages in using homogenous catalyst is the recovery of catalyst from the final product and formation of soap [47]. To overcome this issue most of researchers used heterogeneous catalyst because heterogeneous catalyst is not affected by free fatty acid and moisture present in the raw material. Enzyme catalytic reaction is the slowest reaction among all other catalytic reactions. They can be used for both esterification and transesterification processes. Though the separation of product is easier while using enzyme catalyst, preparation of enzyme catalyst is most critical [53].two of the most commonly used catalysts for transesterification reaction are NAOH and KOH. These catalysts operate by reacting with alcohol according to the reaction given below (written using methanol and NAOH but other alcohols and catalysts could be substituted) [54].

$$(CH_3OH + NaOH \rightarrow CH_3O - Na + H_2O) \quad (3)$$

2.10. Biodiesel fuel quality

The primary criterion for biodiesel quality is adherence to the appropriate standard. In the United States, this standard is ASTM D 6751-02 "Standard Specification for Biodiesel Fuel (B_{100}) Blend Stock for Distillate Fuels." Generally, the fuel quality of biodiesel can be influenced by several factors:

- ✓ The quality of the feedstock.
- ✓ The fatty acid composition of the parent vegetable oil or animal fat.
- ✓ The production process and the other materials used in this process.
- ✓ Post-production parameters.

Table.2.1. shows the property values required for a mixture of methyl esters to be considered biodiesel. When these limits are met, the biodiesel can be used in most modern engines without modifications while maintaining the engine's durability and reliability. Even in low level blends with conventional diesel fuel, the biodiesel blending stock is expected to meet the standard before being blended. While some properties in the standard, such as cetane number and density, reflect the properties of the chemical compounds that make up biodiesel, other properties provide indications of the quality of the production process. Generally, the parameters given in ASTM D6751 are defined by other ASTM standards. However, other test methods, such as those developed for the American Oil Chemists' Society, (AOCS) may also be suitable (or even more appropriate as they were developed for fats and oils and not for petroleum-derived materials addressed in the ASTM standards). This discussion will focus on the most important issues for assuring product quality for biodiesel as it is related to production as well as some post-production parameters.

Table.2.1.ASTM D 6751–02 Biodiesel Specifications [55].

Property	Method	Limits	Units
Flash point, closed cup	D 93	130 min	° C
Water and sediment	D 2709	0.050 max	% volume
Kinematic viscosity,40° C	D 445	1.9 – 6.0	mm^2/s
Sulfated ash	D 874	0.020 max	wt. %
Total Sulfur	D 5453	0.05 max	wt. %
Copper strip corrosion	D 130	No. 3 max	
Cetane number	D 613	47min	
Cloud point	D 2500	Report to customer	° C
Carbon residue	D 4530	0.05 max	wt. %
Acid number	D 664	0.8 max	mg KOH/g
Free glycerin	D 6584	0.02	wt. %
Total glycerin	D 6584	0.24	wt. %
Phosphorus	D 4951	10	ppm
Vacuum distillation end point	D 1160	360 °C max, at T-90	
Storage stability	To be determined	To be determined	To be determined

2.11. Biodiesel Properties and Specification Standards

2.11.1. Biodiesel properties

1. Viscosity is the resistance to flow of a fluid under the influence of gravity. The kinematic viscosity is equal to the dynamic viscosity divided by density. The kinematic viscosity is a basic design specification for the fuel injectors used in diesel engines; moreover the high a viscosity implies the injectors fail to perform properly.

2. Density is defined as mass per unit volume of a substance at a specific temperature. The higher density of biofuel indicates presence of large mass in specific a volume, which is heavy biofuel.

3. Flash point is defined as the lowest temperature corrected to at atmospheric pressure at which application of an ignition source causes the vapors of a specimen to ignite under specified conditions of test.

4. Ash content is the residue remaining after a fuel sample has been burned. For biodiesel, this test is an indicator of the quantity of residual materials in the fuel that came from the catalyst used in the transesterification reaction and raw material used.

5. Acid number is an indication of the presence of free fatty acids in biodiesel. The free fatty acids can lead to corrosion and may be an indication of water in the fuel during manufacturing.

6. Iodine value indicates the level of saturation of the molecules which according to ASTM, the iodine number helps to indicate the oxidation stability of the biodiesel. The higher iodine number represents the lower oxidation stability.

7. Caloric value of a fuel is the standard heat of reaction at constant pressure where the fuel burns completely with oxygen and higher caloric value fuel gives higher heat output.

8. Cloud point of the fuel is the temperature at which wax crystals first begin to be formed. Below the cloud temperature, filters will start to become blocked and potentially starve the engine of the fuel.

9. Water content is the amount of water content in the biodiesel determines the caloric value and the shelf life of the fuel. Biodiesel with higher water content has lower oxidation stability and the greater probability of oxidation products will be formed during long storage period.

10. Cetane number is the measure of fuel's ignition and combustion quality. The higher cetane number biodiesel has lower ignition time delay, which means it, ignites immediately. Fuels with lower cetane numbers will cause hard starting, rough operation, noise and increased smoke opacity in engines.

2.11.2. Biodiesel specification standards

The fuel specification defines and sets the quality standards for biodiesel which is based on the standard ASTM D6751. The kinematic viscosity is equal to the dynamic viscosity divided to the density and is a basic design specification for the fuel injectors used in diesel engines which is the resistance to flow of a fluid under gravity. If the viscosity is too high, the injectors do not perform properly. The viscosity of biodiesel can be predicted ± 15 % using the esters composition determined. The viscosity has to be in a range of 1.9-6.0mm^2/s. 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. 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.

Nevertheless, the acid value may increase with time as the fuel degrades due to contact with air or water. The requirement is a maximum of 0.8 mg of KOH/g oil [56]. The ASTM and EU biodiesel property specifications with the recommended test methods are given in Table 2.2.

Table2.2: Standard Specifications of Biodiesel: USA and European [Source: Adopted from Biodiesel industries, Australia 2003].

Property	Unit	USA	EU	
		ASTM D 6751	EN 14214	Recommended Test method
Density at 15 ^{0}C	Kg/m^{3}	-	860 – 900	ASTM D 4052
Kinematic viscosity at 40 ^{o}C	mm^{2}/s	1.9 -6.0	3.5 - 5.0	ASTM D 445
Flash point	^{o}C	≥ 120	≥ 130	ASTM D 93
Cloud point	^{o}C	-	-	ASTM D 2500
Sulfur content,100%	w%	≤ 0.05	≤ 0.01	ASTM D 5453
Sulphated Ash	wt%	≤ 0.02	≤ 0.02	ASTM D 874
Water content	mg/Kg	-	≤ 500	EN ISO 12937
Total contamination	mg/Kg	-	≤ 24	EN 12662
Water and sediment	% vol.	≤ 0.05		ASTM D 2709
Corrosion (Cu) at 50 ^{o}C	-	≤ No.3	class 1	ASTM D 130
Cetane number	-	≥ 47	≥ 51	ASTM D 613
Acid number	Mg KOH/g	≤ 0.8	≤ 0.5	ASTM D 664
Oxidation Stability ,110℃	hours		≥ 6	EN14112
Ethanol content	wt%		≤ 0.2	EN 14110
Ester content	wt%		≥ 96.5	EN 14103
Carbon Residue,100%	wt%	0.05 max		ASTM D 4530
Triglycerides	wt%		≤ 0.20	EN 14105
Diglycerides	wt%		≤ 0.80	EN 14105
Monoglycerides	wt%			EN 14105
Free glycerol	wt%	≤ 0.02	≤ 0.02	ASTM D 6584
Total glycerol	wt%	≤ 0.24	≤ 0.25	ASTM D 6584
Iodine value	gI_2/100g		≤ 120	EN 14111
Phosphorus	mg/Kg	≤ 10	≤ 10	ASTM D 4951

2.12. Biodiesel lubricity

Lubricity describes the ability of the fuel to reduce the friction b/n surfaces that are under load. This ability reduces the damage that can be caused by friction in fuel pumps and injectors. 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 [57].

Table.2.3. Properties of diesel fuel &cotton seed oil

s.no	property	Cotton seed	diesel
1	Calorific value	39,648KJ/Kg	43,000 KJ/Kg
2	Flash point	234℃	44℃
3	Fire point	192℃	49℃
4	Viscosity	2.52 poise	0.278 poise
5	density	850835Kg/m^3	835Kg/m^3

2.13. Need of blending and its effect on performance

Engelmann reported that 10-50% soybean oil fuel blends with diesel minimize the carbon deposition in combustion chamber [58]. Quick 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 [59]. Blending vegetable oils with fuel was found to be a method to reduce chocking and extend engine life. The similar results were reported by Bartholomew [60],Barsic and Humke [61], working on different oils such as pea nut oil, cottonseed oil, sunflower oil, rapeseed oil, and sunflower oil respectively.

2.14. Fuel additive

Additives improve ignition and combustion efficiency, stabilize fuel mixtures, protect the motor from abrasion and wax deposition, and reduce pollutant emissions, among other features. Two basic trends are becoming more relevant: the progressive reduction of sulphur content and the increased use of biofuel. Several additives' compositions may be used as long as they keep the basic chemical functions that are active [62].

However, there are major drawbacks in the use of biofuel blends as NOx tends to be higher, the intervals of motor parts replacement such as fuel filters are reduced and degradation by chronic exposure of varnish deposits in fuel tanks and fuel lines, paint, concrete, and paving occurs as some materials are incompatible. Here, fuel additives become indispensable tools not only to decrease these drawbacks but also to produce specified products that meet international and

regional standards like EN 14214, ASTM D 6751, and DIN EN 14214, allowing the fuels trade to take place.

2.14.1 Types of Additives

2.14.1.1. Metal-Based Additives

Some metal-based additives are reported to be effective in lowering diesel emissions. They may reduce diesel emissions by two ways. First, the metals either react with water to produce hydroxyl radicals, which enhance soot oxidation, or react directly with carbon atoms in the soot, thereby lowering the oxidation temperature. When these additives are used after combustion in the engine, the metal acts as a nucleus for soot deposition. Usually, the additive is added as a metal-organic compound, and it is emitted in the particulate phase as oxide, on soot particles or forming new nanometer-sized particles by homogeneous nucleation of the additive. Particle traps are suitable tools for minimizing soot emissions. However, a technical challenge is the regeneration of clogged filters because online regeneration demands a minimum temperature of 550 °C and an oxygen content of 5%, which cannot be attained without additional burners or catalytic combustion. The principle of this additive action consists of a catalytic effect on the combustion of hydrocarbons [63].

2.14.1.2. Oxygenated Additives

Another group of fuel additives is oxygenated compounds. The idea of using oxygen to produce a cleaner burning of diesel fuels is half a century old. Since that early work, numerous researchers have reported the addition of a variety of oxygenated compounds to diesel fuel. Some oxygenate compounds used are ethanol, acetoacetic esters and dicarboxylic acid esters, ethylene glycol monoacetate, 2-hydroxy-ethyl esters, diethylene glycol dimethyl ether, sorbitan monooleate and polyoxyethylene sorbitan monooleate, dibutyl maleate and tripropylene glycol monomethyl ether, and dimethyl ether, dimethyl ether (DME), dimethyl carbonate (DMC) and dimethoxy methane, 1-octylamino-3-octyloxy-2-propanol and N-octyl nitramine, dimethoxy propane and dimethoxy ethane, biodiesel, and a mixture of methanol and ethanol[63].

Oxygenated additives have been considered for reducing the ignition temperature of particulates. However, the reduction of particulate emissions through the introduction of oxygenated compounds depends on the molecular structure and oxygen content of the fuel and also depends on the local oxygen concentration in the fuel plume.

2.14.1.3. Depressants and Wax Dispersants

Petroleum distillate fuels contain n-paraffin waxes that tend to be separated from the oil at low temperatures. The waxes generally crystallize as an interlocking network of fine sheets, thereby trapping the remaining fuel in cage-like structures and causing cold-flow problems such as clogging of fuel lines and filters in engine fuel systems. Several techniques have been used to minimize the problems caused by the wax deposition, and the continuous addition of polymeric inhibitors is considered to be an attractive technological alternative [63].

2.14.2. Biodiesel Additives

Additives play a very important role in meeting the international fuel standards and real time problems which are associated with biodiesel. With the help of additives the fuel properties can be enhanced and biodiesel in blend can be used with diesel in the vehicle which able to increase the performance and reduction in exhausts emissions from the engine. The selection of biodiesel additives is mainly based on different properties of additives such as flash point, fire point, viscosity, density, calorific value, solubility etc. [64].

The use of additives in biodiesel also solves many technical problems which limits the acceptability of biodiesel as an alternative fuel in all conditions. Table.2.4 shows the different properties of biodiesel additives.

Table.2.4.properties of some selected additives for comparison

Additive	Kinematic Viscosity at 40℃	Density (kg/m^3)	Calorific value (kJ/g)	Cetane number	Flash point (^0C)
Ethanol	1.14	791	27.33	5-8	16
n-Butanol	3.00	812	34.33	25	35
Diethyl Ether	0.22	712	33.89	25	-
Methanol	0.59	790	19.62		11

Ethanol contains s 34% higher oxygen by weight. Biomass can be converted to the ethanol by using the process of fermentation from the different feedstock the ethanol can be produces such as sugarcane, sugar beet, sorghum, potatoes, sunflower, molasses, corn , wheat, cotton etc. [65]. Oxygenated fuels are generated because of addition of ethanol in diesel fuels. Ethanol with diesel is also named as Diesohol. Many investigators documented that addition of ethanol in small percentage in the blends of biodiesel increases the brake thermal efficiency, increases the rate of

heat release, reduces the viscosity and reduces the smoke in the exhaust of the engine. Also the physical and thermal properties of ethanol-biodiesel –diesel blends improved drastically which helps the combustion [66].

Diethyl ether is also an oxygenated additive which is biomass based produced from the ethanol. It is colorless fuel. It possesses high volatility. It also have high tendency to respond to low temperature because of high flammability. It has high cetane index. But on the other side the heating value of diethyl ether is lower than conventional diesel. But it used to mix with biodiesel or diesel easily. It has good solubility characteristics. Many investigators reported that addition of diethyl ether with diesel–biodiesel blend improves the properties of the blend and enhanced the performance and reduced the engine pollutants [67].

In past few years n-butanol is also emerged as an additive for the biodiesel –blend because of its higher percentage of O_2 content. It is also refer as 1-butanol and produced from fermentation of different feedstock of biomasses. It has straight chain with OH group and has lower hydrophilic nature. High cetane number, good solubility and higher heat content attract many researchers to consider n-butanol as an additive to biodiesel-diesel blends [67].

Due to the poor cold flow properties of biodiesel-diesel blend it is not possible to use the blend in cold weather condition without the additives. Ethanol is also a very promising alternative additive higher level of oxygen which is basically responsible to enhance the rate of combustion in the cylinder. It is an analysis grade anhydrous ethanol of purity 99.9%. Ethanol is easily available in and produced in some Ethiopian sugar factory. Because of all such type of properties, and easily availability it is the strong competitor as an additive in the biodiesel–diesel blend.

2.15. Ethanol-Diesel Blends

Bioethanol, biodiesel and to a lesser extent pure vegetable oils are recently considered as most promising biofuels.

Since 19th century, ethanol has been used as a fuel for diesel engines. Ethanol is a low cost oxygenated compound with high oxygen content (34.8%) and often chosen because of the ease of production, can be obtained from various kinds of biomass such as corn, sugar beet, sugarcane, cassava, maize, red etc., [68].

Blends of ethanol with diesel fuel are often referred to as “E-Diesel” or “eDiesel”. Sometimes, ethanol-diesel blends are also called “oxygenated diesel” a term that is not particularly precise, as diesel blends containing methyl ester biodiesel or any other additive that includes oxygen can be also described as oxygenated diesel.

In e-diesel blends, standard diesel fuel is typically blended with up to 15% (by volume) of ethanol using an additive package that helps maintain blend stability and other properties, most importantly cetane number and lubricity. The additive package may comprise from 0.2% to 5.0% of the blend.

The use of e-diesel can bring some reductions in diesel PM emissions, while contradictory reports exist on its effect on NOx, CO, and HC emissions. Perhaps the biggest advantage of e-diesel is its partially renewable character, if renewable ethanol is used as the blending stock. Considering its potentially significant operational and safety issues the latter including very low flash point e-diesel will likely remain a niche market fuel of limited applicability.

Ethanol fumigation into the engine intake port is an alternative way to use ethanol in the diesel engine. The method even though requires modifications to the engine; its application remains even more limited. Aftermarket dual fuel kits have been developed that allow port fuel injection of ethanol. Some kits also incorporate a heat exchanger to preheat the ethanol to a temperature of 50-80°C to improve fuel vaporization in the intake port. In one study, hydrous ethanol (90% by vol.) was fumigated into the intake port of a diesel engine. The engine was operated with ethanol substitution rates up to 37%, based on the fumigant energy fraction (FEF), but the effect on emissions was marginal. As FEF increased, NO emissions decreased, but the NO reduction was balanced by an increase in NO_2 emissions. Emissions of CO, and ethanol all increased with the FEF, while soot emissions generally decreased [68].

When the ethanol content was prepared for blending of diesel-biodiesel small amount of reagents needed to be used to stabilize the mixture or attain the required cetane number. Choosing a suitable organic additive meets with several difficulties. Certain compounds (alkylperoxides) show reduced efficacy in the presence of ethanol or are not even miscible in fuel–alcohol blends (polyethylene glycol dinitrates). For this research TWEEN80 was used due to easily available in Ethiopian market.TWEEN80 is Polysorbate 80 is a nonionic surfactant and emulsifier often used

in foods and cosmetics. This synthetic compound is a viscous, water-soluble yellow liquid. It used as stabilizer of ethanol blend with diesel-biodiesel.

2.16. Engine performance

Studies and researches were carried out on the properties, performance of biodiesel in diesel engine locally as well as outside.

Tesfahun Tegegne Akanaw (2014)

Worked his final thesis paper on Castor Seed from Melkasa Agricultural Research Centre, East Showa, Ethiopia and its biodiesel performance in Four Stroke Diesel Engine

He produced biodiesel from castor seed and compared its performance characteristics with that of petro diesel in the existing four stroke cycle diesel engine without making any modifications to it. The results from the research are illustrated as follows.

All the tests from characterization of biodiesel demonstrated that, almost all the important properties of biodiesel (except for B_{100} & B_{80}) are in very close agreement with the mineral diesel, making it a potential candidate for the application in CI engines.

The experiment showed that castor seed has higher biodiesel yield and the characterization results witness that biodiesel from castor seed can be blended with petro diesel in order to minimize the problems that can arise from its higher viscosity while using the neat biodiesel in unmodified diesel engines. Hence, the research shows a good bright future, that it is possible to produce an everlasting and safer fuel above the earth's surface which can potentially substitute petro diesel.

The performance test results depict the tested blends (B_5, B_{10}, B_{20}, and B_{40}) perform almost similar when compared with the performance of petro diesel. The torque and power performances get reduced and fuel consumption increase as the percentage of biodiesel in the blends increase. This is because of the fact that biodiesels are oxygenated fuels and hence has less energy content compared to petro diesel. But this little reduction in performance can be compensated with lots of its advantages like its usage in unmodified engine, better lubricity, renewability, degradability, very less contribution to global warming, and its provision of great ecological advantages in terms of erosion control and wasteland recovery.

The performance characteristics showed that diesel engine can perform satisfactorily on biodiesel blends without any engine hardware modifications.

The performance result also showed that out of the blends, B_5 is most nearer to petro diesel performances and hence it is possible to start driving diesel engine vehicles with 5% biodiesel and 95% petro diesel blend. But small generators and water pump engines (because the load imposed on them is not that much bigger) can be fuelled with B_{20}, a 20% biodiesel and 80% petro diesel blend; which brings a great cost reduction especially for farmers (because biodiesel can be locally produced).

Feleke Tesfaye Bruke (2016)

Performed test on Biodiesel which was prepared from purified castor oil with methanol and KOH through transesterification method in the laboratory scale batch production. He was determined The oil content of the castor seeds, in which the oil content resulted for the extraction experiments were on average 52% by mass. After conducting the experiment he was found that maximum biodiesel yield of 92.08% obtained. He prepared seven samples of fuels such as (B_{10}, B_{15}, B_{20}, $B_{10}DEE_5$, $B_{15}DEE_5$ and $B_{20}DEE_5$) and conventional diesel fuel. He tested fuels produced at laboratory scale and used additive DME and measured the kinematic viscosities. He found that castor biodiesel has higher kinematics viscosity, this result in poor atomization of the fuel. Therefore the biodiesel has to be blended with petro diesel and a DEE additive has to be used.

Derese Firew

He was performed on the performance evaluation of diethyl-ether (DEE) additive with Diesel blends using Diesel Engine test rig. In this work, he was carried out trans-esterification reaction using the non-edible jatropha oil and alkali methoxide. He used 20g/liter the quantity of potassium hydroxide catalyst at a reaction time of 1 hour, reaction temperature of 65 ^{0}C and molar ratio of oil to methanol as 5:1 for optimal biodiesel yield of 95.5%.

He analyzed and compared the performance characteristics of diesel, JOME and JOME-DEE blends. The Brake power of B_{20} + 20% DEE is found to be higher than that of other biodiesel blends but lower than the B_0. The higher Power after the addition of DEE to JOME is due to its oxygen content and effect on lowering the viscosity of the blend, which led to an improvement in the combustion. The brake specific fuel consumption for B_{20} + 10% DEE is lower than that of the others at the maximum load, however at lower load conditions B_{20} + 20% DEE gives the lowest break specific fuel consumption.

Marta Zeleke (2016)

Performed test on exhaust gas analysis & parametric study of cotton seed biodiesel in diesel vehicle. By doing extraction and transesterification reaction of cotton seed and crude cotton seed oil she produced biodiesel and characterized for some selected properties of biodiesel. Then, she prepared biodiesel blends B_{10}, B_{20} &B_{30} and perform performance test and emission test. From her test result:-

1. The properties of cotton seed biodiesel and its blends conform to ASSTM D6751 standards.
2. The torque & power performance get reduced and fuel consumption increased as the percentage of biodiesel in the blends increase.
3. The biodiesel blends produced lower emission with drop in CO, CO_2 & HC emission while NO_X & O_2 emissions are show on a little increment compared to the petroleum fuel.

Tanzer Eryilmaz

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 of biodiesel was found higher than diesel fuel [69].

The kinematic viscosity of biodiesel and diesel fuels decreases exponentially with increasing temperature. The kinematic viscosity of blend fuels increases with increasing increase the pure biodiesel blend ratio. The calorific value of fuels decreases linearly with blend ratio. The calorific value of the B_{100} was found lower than diesel fuel.

Sathiyagnanam

He described that on the difference blends of 25%, 50% & 75% cottonseed biodiesel the performance &emission of CI engine have been measured. Therefore, significant engine performance parameter 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 chamber temperature, which leads to higher NOx emission, especially at high engine loads [70].

Siva Kumar

Performance & emission test on a single cylinder four stroke engine, various blends of biodiesel such as B_0, B_5 B_{10} were used. Thermal efficiency with biodiesel mixture was slight lower than that of neat diesel fuel due to lower heating value of mixtures. Biodiesel mixture showed less CO, PM, smoke emission than those of neat diesel fuel [71].

Mojtaba Saei Moghaddam (2012)

"Performance and Exhaust Emission Characteristics of a CI Engine Fueled With Diesel Nitrogenated Additives" Nitro-Methane (NM) and Nitro-Ethane (NE) were used as nitrogenated additives to improve brake specific fuel consumption (BSFC) ,combustion performance and reduce emission from diesel engine. Then exhaust emission of compression ignition (CI) engine have been evaluated experimentally for sole diesel, NM-Diesel and NE-Diesel fuel blends. The addition of nitrogenated additives to the standard diesel fuel caused brake thermal efficiency (BTE) increased. The smoke emission decreased at the maximum torque speed (1500 rpm) rather than at the rated power speed (2200 rpm).

Overall, NE has been found to be promising fuel additive in compare with another additive, capable of providing high thermal efficiency, low soot levels and decreased viscosity but have high level of NOx at the maximum torque speed (1500 rpm). Nitrogenated additives increased brake thermal efficiency (BTE), in all modes, the average smoke reduction rates of NM-Diesel and NE-Diesel were 16.2% and 35.7% of that of sole Diesel respectively.

K.Velmurugan, S.Gowthamn. (2012)

He worked on ''Effect of Cetane Improver Additives on Emissions.'' NOx is very undesirable. Regulations to reduce NOx emissions continue to become more and more stringent year by year. Released NOx reacts in the atmosphere to form ozone and is one of the major causes of photochemical smog. NOx is created mostly from nitrogen in the air. Nitrogen can also be found in fuel blends. At high temperature and pressure higher levels of NOx is created and at low temperature lower level of NOx is produced. In addition to temperature, the formation of NOx depends on pressure and air-fuel ratio. Engine emission from diesel fuel, paying special attention to the most concerning emissions. Many of the design changes for reduction in NOx emissions

result in higher brake specific fuel consumption. Cetane number describes the auto ignition quality of the diesel fuel. Cetane improver additive of neopentane is used with the varying proportions of 1ml, 3ml, and 5ml to the diesel fuel respectively. Addition of cetane improver additive to the diesel fuel is cost effective way to control NOx emission. Diesel fuel with the 3ml additive of neopentane shows the significant reduction in NOx and smoke .The sensitivity of NOx to change in cetane number is higher at low load than at high load. It is found that NOx emissions were reduced at low load than at high load.

A. Rama Krishna, B. Prabakaran (2015)

"Performance And Emission Characteristics of Cottonseed Oil Methyl Ester in a Diesel Engine'' Cottonseed oil biodiesel is having higher cetane Number than diesel and higher viscosity than diesel and cottonseed oil is non-edible oil. Blends of biodiesel from cottonseed oil has been made in various proportions up to 30% volume with diesel and tested in a diesel Engine. Results show that the emissions of carbon monoxide (CO) and unburned hydrocarbon (UHC) has reduced for all the blends. Brake specific energy consumption for all the blends is lower than that of diesel. There was Increase in brake thermal efficiency for all the blends than diesel fuel. There was slight increase in oxides of Nitrogen (NOx) for all blends.

Chandan Kumar, Ashishnayyar. (2012)

He worked on "Analysis of Emission Characteristic of NM-Diesel Blend on VCR Diesel Engine" Emission contents smoke and NOx can be reduced by adding additives with diesel fuel. As these additives are very costly and hence becomes unviable. These additives decrease the performance of combustion. Oxygenated compounds are most widely used among additives. The reason for this is the participation of their oxygen in reactions leading to better combustion and hence lowering the emission contents the molecular structure of the oxygen contents of additives directly influence on smoke reduction and the oxygen concentration of the fuel flame also effects the emission specially Nitro paraffin compound additives have high oxygen contents is then molecular structure.

Only NOx has been reduced by lowering the compression ratio, otherwise CO, HC and smoke has been increased due to reduced compression ratio. Thus it is concluded that lowering the compression ratio from normal (i.e. 17.5 to 16.5) is not in favour for emission of CI Engine with NM-Diesel blend.

M. Martin, D. Prithviraja (2011)

"Performance of Pre-Heated Cottonseed Oil and Diesel Fuel Blends in a Compression Ignition Engine.'' A remarkable improvement in the performance of the engine is noticed as the viscosity of the oil is reduced. Brake thermal and volumetric efficiencies of the engine increased with a significant reduction in the exhaust gas temperature. Reductions in smoke, CO and HC emissions are also noticed. Results show that a blend containing 60% of cottonseed oil with diesel, which is heated to a temperature of 70°C, can be used as an alternate fuel without any engine modification.

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

As my understanding from the review of the literatures, that biodiesel blended fuels with additives can effectively reduce the environmental pollution without any major modification to the design of the engine .therefore, in this study the cotton seed biodiesel with ethanol is used in diesel as additive fuel. Finally the intention in the thesis work is testing the performance of cotton seed biodiesel with ethanol in diesel engine to improve the engine performance.

3. MATERIALS AND METHOD

3.1 Materials

The crude cotton seed oil, Methanol, Potassium hydroxide, ethanol for blending in biodiesel, Diesel fuel, tween80 as reagent, Distilled water and aluminum foil were obtained from chemical selling and suppliers companies in Ethiopia found in RANCHEM CHEMICAL SUPPLIER and YESHADAM TRADING PLC for laboratory scale amount. All chemicals used for the research were analytical grade.

Additional materials were used for this research: reactor, flask, beaker, funnel, measuring cylinder, Separator funnel, protective equipment, 4-stroke diesel engine, engine dynamometer/chassis dynamometer, thermometer, and hot plate with magnetic stirrer, digital balance and glassware. Using tabular form materials used equipment's used for biodiesel production are listed below.

Table 3.1 materials used for biodiesel production

S.NO	List of materials
1	Cotton seed
2	Crude cotton seed oil
3	methanol
4	Potassium hydroxide

Table 3.2.equipments used for biodiesel production

S.NO	List of equipment's
1	Separator funnel
2	Stand for separator funnel
3	Conical flask
4	thermometer
5	Glass ware, beaker
6	Magnetic stirrer with hot plate
7	Aluminum foil for covering during reaction
8	Digital weighing scale

3.2 Methodology of the research

The methodology of the research were the Small scale laboratory production of biodiesel from crude cotton seed oil, methanol as reactant and potassium hydroxide catalysis through transesterification methods and the performance of cotton seed biodiesel and petro diesel blends with ethanol as additive were conducted in a four stroke diesel engine in ASTU.

This research was done mainly based on experimental activities. The methods and procedures used in this thesis work were the following.

- Sample collection from Addis Modjo Edible Oil Factory.
- Extraction of oil by mechanical pressing.
- Transesterification reaction.
- Characterization of pure biodiesel and blends of biodiesel with additive ethanol using different parameters.
- Preparation of blends of fuel with additive ethanol, performance test set up
- Perform the performance test of pure diesel and diesel biodiesel blends with additive of ethanol in a vehicle (in diesel engine).
- Comparing the test result from pure diesel and diesel biodiesel blends with additive ethanol according to performance parameters.

Crude cotton seed oil was extracted from expeller, Addis Modjo Edible Oil Complex Company (i.e. screw pressed cotton seed oil) by mechanical pressing. Methanol, potassium hydroxides were obtained from an agent of yeshadam chemical trading plc. in Addis Ababa. Transesterification reaction and blending process with additive ethanol was done in chemistry department of ASTU. Performance test was carried out in automotive workshop of ASTU Conventional diesel fuel purchased from outlets nearby.

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 and the seed for oil extraction to oil producing factory.

3.2.2 Feed Material Requirement for Biodiesel Production

For every run 500ml of purified cotton seed oil was used. Hence, the amount of methanol and catalyst was calculated using the process parameters. The amount of methanol required when the molar ratio of methanol to oil ratio 5:1;

Process variables revised are reaction temperature, molar ratio of methanol to oil and weight percentage of catalyst. To get maximum conversion; reaction period and rotation speed was set at 2 hours and 500 rpm respectively and at constant atmospheric pressure.

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 and separation of hulls(husk)
- Heat treatment
- Mechanical pressing
- Filtering

Oil seed cleaning

- ✓ The raw material cotton seed was conveyed to pre cleaner to remove foreign matters, stones dust and impurities. The seed also passed through magnetic separation to trap metallic impurities.

De hulling and separation of (hulls) husk

- ✓ The cleaned cotton seed was conveyed and 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 at temperature of 80-110℃ by steam. Its purpose is to adjust natural moisture content of the seed (3-6%) coagulate protein and makes the seed permeable to the flow of oil, reduce viscosity of oil and sterilize the seed, destroy enzymatic action to prevent growth of mould and bacteria. The time takes for cooking was 90 minutes.

Mechanical pressing

- ✓ Conveyed the cooked oil seed for screw pressing, screening and pumping the crude oil was extracted and cake part separated.
- ✓ Finally the extracted crude cotton seed oil was filtered from impurities.

3.2.3. Determination of Crude Cotton Oil Content

- ✓ The amount of processed cotton seed for oil extraction was 50kg which were crushed/ broken into small pieces and processed mechanically in the machine.
- ✓ By the first outlet found the crude oil by the other outlet the cake or residue.
- ✓ Finally 10 liter crude cotton seed oil was produced/extracted.
- ✓ After the crude oil was collected from the factory, transesterification process was taken place in Adama Science and Technology University, Chemistry Department Laboratory.

3.2.4 Transesterification of cotton seed oil

Transesterification of cotton seed 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 reason 5gm of potassium hydroxide was involved in 100ml 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 500ml of crude cotton seed oil.

The transesterification process of producing cotton seed biodiesel

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

Fig.3.1 Measured crude cotton oil sample.

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

Fig.3.2. Methanol and potassium hydroxide and 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℃.

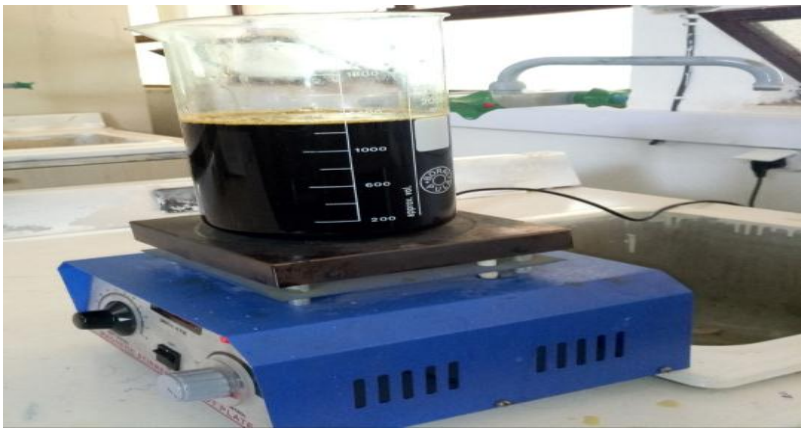

Fig.3.3. Heating the crude oil

5) Add the dissolved mixture (KOH & methanol) into the heated oil.

6) Heat the dissolved mixture for 1hr at fixed temperature of 65℃, heating, and 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℃). After 1hr, switch off the heating mantel to stop the reaction process.

Fig.3.4. Heating the mixtures of KOH &methanol) with crude oil.

7) When the reaction time reaches around 45minutes glycerin starts to separate and settle at the bottom, and a clear solution appears at the bottom.
8) On completion of the transesterification process, the products were poured into separating funnel for 24hs. Two phases (having different density) were formed.

Fig.3.5. the heated mixtures of KOH &methanol) with crude oil was poured into the reparatory funnel

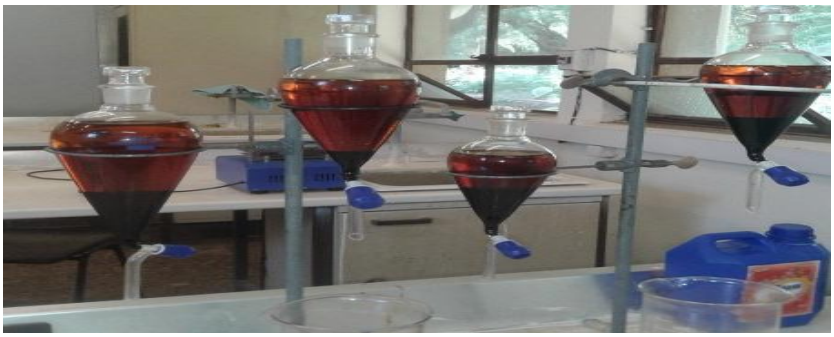

Fig.3.6 Two layers of oil formed

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 was drained. The glycerin can be used to make soap.

a) When glycerin & fatty acid drained b) drained glycerin & fatty acid

Fig.3.7. upper layer (biodiesel) & 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℃.

Fig. 3.8 washing of biodiesel with distilled water.

Washing of biodiesel was performed under the following procedures

- ✓ Distilled water was heated at 55℃.
- ✓ The biodiesel was poured in a separator funnel.
- ✓ The water and soap settled at the bottom and separated by opening the valve of the funnel. Repeat washing process six times until water is mostly clears.

Fig.3.9. 1st step washing of biodiesel with distilled water (soap formation)

Fig.3.10. soap and impurities during washing process

Fig.3.11.3rd and 4th washing process

Fig.3.12. final washing step, water becomes clearer

Fig.3.13. biodiesel after washing process

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

Fig.3.14. heating and drying biodiesel

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

Fig.3.15. produced and collected biodiesel using empty and clean distilled materials/plastics (inside dried plastics of one liter each)

3.2.5. Production of biodiesel layout

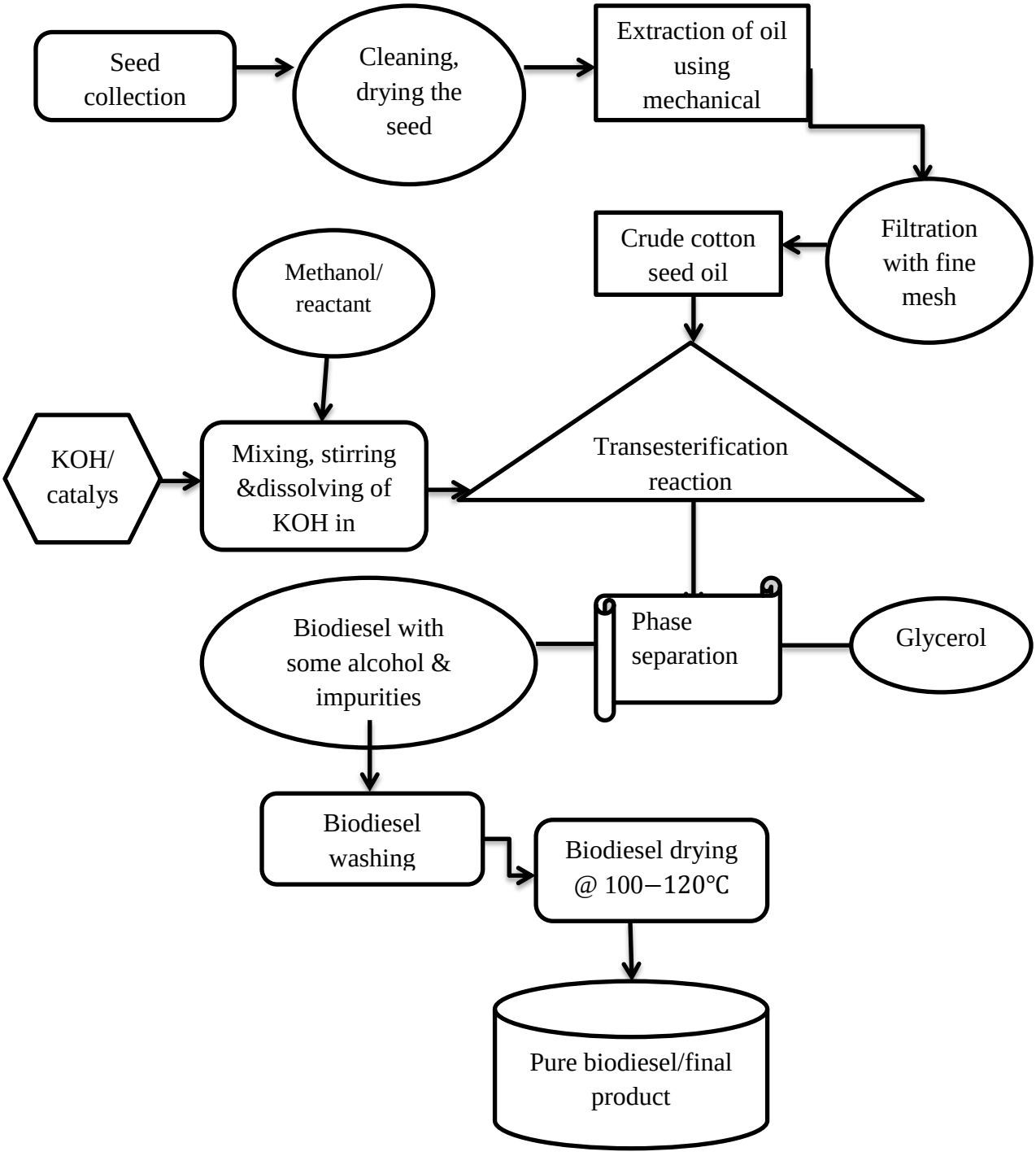

Fig.3.16. layout for the production of biodiesel

3.2.6. 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 of blend of B_{20} with additive ethanol fuel it's very important to check physicochemical properties. The properties of the fuel include kinematic viscosity, flash point, acid number, density and pour point.

Fuel blend prepared for characterization is B_{20} with 3 different amount of ethanol as additive i.e. $B_{20}E_5$, $B_{20}E_{10}$ & $B_{20}E_{15}$.for blend miscibility tween 80 was used in small amount 1.5% to 4.5% in this test. To prepare $B_{20}E_5$ blend fuel 20% of cotton seed biodiesel mixed with 75% of diesel and 5% of ethanol as additive and very small amount of tween 80 was used. For $B_{20}E_{10}$ blend fuel 20% of cotton seed biodiesel mixed with70% of diesel and 10% of ethanol and For $B_{20}E_{15}$ blend fuel 20% of cotton seed biodiesel mixed with 65% of diesel and 15% of ethanol were used for the purpose of characterization.

The above mentioned physical properties are performed in Ethiopian Petroleum Supply Enterprise (Quality Control Laboratory).

a) $B_{20}E_5$+1.5%TWEEN80 b) $B_{20}E_{10}$+3%TWEEN80 c) $B_{20}E_{15}$+4.5%TWEEN80

Figure.3.17. biodiesel and blends of biodiesel with additive ethanol and tween 80

3.2.6.1. 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℃.

Digital density analyzer: - digital density analyzer consists of 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 (about1 to 2ml) 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. After the instrument display a steady reading to four significant figures for density, relative density, API gravity or both, as appropriate. If the two determinations do not differ by more than 0.0002g/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℃=0.876.5g/ml or876.5kg/m^3).report the final result for density or relative density to four significant figures [72].

3.2.6.2. Determination of flash point (FP) [ASTM D93]

The flash point was measured with standard test method Pensky-Martens Closed Cup Tester using ASTM D93.

ASTM D93 stands for standard test methods for Flash Point by Pensky-Martens Closed Cup Tester. In these cases a manual Pensky-Martens closed-cup apparatus or an automated Pensky-Martens closed-cup apparatus are used. The methods cover the determination of the flash point of petroleum products in the temperature range from 40 to 370°C, and of biodiesel by an automated Pensky-Martens closed cup apparatus in the temperature range of 60 to 190°C [73].

Pensky–Martens closed-cup test: - in the Pensky–Martens closed-cup flash-point test, a brass test cup is filled with a test specimen/biodiesel/diesel and fitted with a cover. The sample is heated

and stirred at specified rates depending on the material that is being tested (biodiesel/diesel). An ignition source is directed into the cup at regular intervals with simultaneous interruption of stirring until a flash that spreads throughout the inside of the cup is seen. The corresponding temperature is biodiesel/diesel flash point [74].

Pensky–Martens closed cup is sealed with a lid through which the ignition source can be introduced periodically. The vapor above the liquid is assumed to be in reasonable equilibrium with the liquid. Closed cup testers give lower values for the flashpoint than open-cup testers(typically 5–10 K) and are a better approximation to the temperature at which the vapor pressure reaches the "lower flammable limit" (LFL) [75].

3.2.6.3. Cloud point (CP) determination (D2500)

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

- ✓ Ice and water up to 10℃,
- ✓ Crushed ice and sodium chloride crystals, up to −12℃,
- ✓ Crushed ice and calcium chloride crystals, up to −26℃

The cloud point was determined by virtually 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 (℃) that corresponds to the formation of first cloud in the fuel was recorded.

3.2.6.4. Determination of kinematic viscosity (ASTM D445)

Kinematic viscosity of biodiesel, biodiesel blended and with additive ethanol 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 the bath heated to 40℃ , sample fuel is filled in the capillary viscometer tube and inserted in the bath and kept for 30minutes 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 calibrated viscometer. Kinematic viscosity is then calculated as the product time (t) in second and the calibration constant (K) of the viscosity tube [76].

Designation

Kinematic viscosity$= K \times t$ (3.1)

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

t=time in second

3.2.6.5. Determination of acid number (ASTM D974)

Standard alcoholic KOH solution (0.1M) was prepared by dissolving 6gm of KOH (pellet) to one liter of anhydrous isopropyl alcohol (anhydrous$< 0.9\%$ water) in a 2L flask and boiled for 15minutes, while stirring. 2gms of $Ba(OH)_2$was added and again boiled for 10 minutes, 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 0.5ml of the indicator solution was added and stirred until sample is completely dissolved in the solvent to form yellow orange color. The solution is then titrated below a temperature of 30℃ 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 and 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 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.

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 $(mgKOH/g)$) was calculated using the f/g relation/formula.

$$AN = \frac{(V_A - V_B) \times N \times 56.1}{Wo} \quad (3.2)$$

Where: - Wo =Sample weight (gm), V_A = Volume of KOH used for the sample (ml),

V_B = Volume of KOH used for the blank (ml) and N= concentration of KOH used (molar)

3.2.6.6. Determination of cetane index (ASTM D976)

Cetane index - (ASTM D976 or ASTM D4737) the cetane index is 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 [77].

ASTM standard D976 gives the following empirical equation for the cetane index:

Cetane index=454.74-1641.416D+774.74D^2-0.554B+97.803[log B]

Where, D=fuel density at 15℃ in g/ml, B=corrected mid boiling point ℃

3.2.7. Blending of cotton seed biodiesel with diesel fuel and additive ethanol

To test on the vehicle, blend fuel were prepared per each sample test $B_{20}E_5$, $B_{20}E_{10}$, $B_{20}E_{15}$ and stirred thoroughly. The mixture was allowed to settle for around 6-7hrs. For miscibility or phase separation and consistency. In this study the method used to blend the cotton seed biodiesel with conventional diesel fuel and ethanol is splash mixing type rather than inline mixing type because, biodiesel is slightly heavier than conventional diesel fuel and ethanol. The specific gravity of ethanol is less than conventional diesel and biodiesel. This allows use of splash blending by adding biodiesel on top of ethanol and diesel fuel for making biodiesel blends of $B_{20}E_5$, $B_{20}E_{10}$, and $B_{20}E_{15}$. First ethanol was blended with diesel by using small amount of reagent TWEEN80 for miscibility. Biodiesel should always be blended at top of diesel fuel blended with ethanol. If diesel fuel blended with ethanol is added at top of biodiesel fuel, it will not mix.

3.2.8. Experimental facilities for the test

The experimental set up used in this investigation is shown below the performance measurement were carried out in the department of mechanical & vehicle engineering work shop of Adama science and technology university.

The test was performed on 3L Toyota vehicle using sun road-a-matic XII chassis dynamometer. The fuels used as a reference were petro diesel & a blend of B_{20} with additive ethanol and tween80 for miscibility of ethanol with diesel plus biodiesel were prepared. The prepared samples were B_0, $B_{20}E_5$+1.5%TWEEN80, $B_{20}E_{10}$+3%TWEEN80 and $B_{20}E_{15}$+4.5%TWEEN80. Initially the engine was tested with pure diesel and later on with blends of the COME with diesel and ethanol were prepared, analyzed and compared with diesel fuel, and comparison was made to suggest the better option among added percentage of ethanol fixing biodiesel as B_{20}.

Table.3.3.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

Fig.3.18.chassis dynamometer and checking its working vehicle performance test

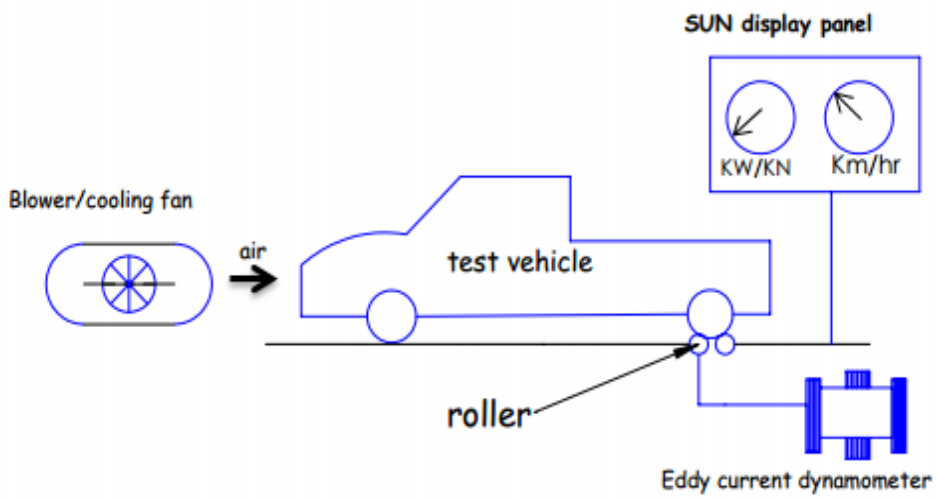

Fig.3.19.schematic representation of performance test work

3.2.9. Performance test procedure in diesel vehicle

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 25 km/hr. on the sun road –a-matic XII chassis dynamometer with 10km/hr interval up to 85km/hr. The experiment was conducted in first gear, second gear, third gear and fourth gear the volume flow rate of fuel was recorded. The performance of engine with blends of B_{20} biodiesel with ethanol and small amount of tween80 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 & $B_{20}E_5$+1.5%TWEEN80, $B_{20}E_{10}$+3%TWEEN80 and $B_{20}E_{15}$+4.5%TWEEN80.

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 parameter has been read & record from the dynamometer & also emission test results recorded.

5. And such parameter 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

The crude oil was extracted from cotton seed by mechanical press machine. From 50 Kg of cotton seed the produced cotton crude oil was 10L which is 20% (v/wt). Oil extraction by mechanical pressing is economical and time saving method.

4.2. Production of biodiesel

From 10L of crude cotton seed oil biodiesel production yield was 8.2L which is 82% by performing transesterification reaction process by keeping the proportion of reactants and conditions of reaction as mentioned in table.4.1. given below. The activities like glycerin separation, washing thoroughly minimum of 3 times and 6-7 times for best separation with warm distilled water about 55-60℃ and drying by heating up to 100−120℃ for 1hr- 45minute respectively were performed in the oven.

The transesterification reaction was done in proportion of table listed below.

Table.4.1.Transesterification reaction

Amount of cotton seed oil(ml)	250
Molar ratio of methanol to oil	5:1
Catalyst(KOH)%	1.0 or 2.5gm in mass
Amount of methanol alcohol in (ml)	50
Reaction time in (hr.)	1 or 60minutes
Reaction temperature in (℃)	60-65
Settling time after reaction in (hr)	24
Settling time after final washing in (hr)	24
Drying time	45minute-1hr

4.3. Result from characterization of blend fuels

Table.4.2.characterization of blended fuels

S.no	property	Test Method ASTM	EPSE Diesel Limits	ASTM D6751* Limit for B_{100}	Test result			
					Cotton seed	5% ethanol B_{20} 5% ADO	10% ethanol B_{20} 70% ADO	15% ethanol B_{20} 65% ADO
1	Density @15℃, g/ml	D4052	Report (N/S)	-	0.8885	0.8577	0.8563	0.8548
2	Density @20℃, g/ml	D4052	Report (N/S)	-	0.8850	0.8542	0.8528	0.8513
3	Flash point(PMCC), ℃	D93	Min. 60	Min. 93	>116			
4	cloud point, ℃	D2500	Max. +5	Report /(N/S)	+7	-3	-3	-3
5	Kinematic viscosity at 40℃, mm^2/sec	D445	1.9-6.0	1.9-6.0	5.50	3.56	3.44	3.37
6	Total acidity, mgKOH/g	D974	-	Max. 0.5	0.3	0.04	0.04	0.05

N/S Means Not Specified

After making the blend of B_{20} and adding additive ethanol with increment of 5% to the blend starting from $B_{20}E_5$ the properties of $B_{20}E_5$, $B_{20}E_{10}$, $B_{20}E_{15}$ & pure biodiesel were measured.it is observed that the values are with in ASTM specification. Then performance test was conducted on the vehicle.

4.4. 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 using sun road-a-matic XII chassis dynamometer found in department of mechanical and vehicle engineering work shop of ASTU.

a) Tractive effort

Tractive effort or tractive force or traction is the force applied b/n 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, that is, the weight of the vehicle and the adhesion coefficient b/n 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 b/n the tires and the road.

$$F_{tr} = {}^{T_W}/_{r_w} \qquad (4.1)$$

$T_W = F_{tr} * r_w$ Where T_W =wheel torque, F_{tr} =tractive force and r_w =radius of the wheel

b) Power at wheels

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

$$P_w = \eta_t * P_P \qquad (4.2)$$

Where P_w=wheel power, η_t= efficiency of the transmission

P_P =engine power

The wheel power data for B_0, $B_{20}E_5$+1.5%TWEEN 80, $B_{20}E_{10}$+3%TWEEN 80, $B_{20}E_{15}$+4.5%TWEEN 80 are given in the tables below.

4.4.1. Wheel power data and their graphs

1. Wheel power data for B_0 (KW)

Table.4.3. Wheel power for B_0

V. Speed(km/hr)	1st gear	2nd gear	3rd gear	4th gear
25	35	31	20	12
35	33	37	26	17
45		41	31.5	23
55		33	39	31
65			31	36
75			25	26
85			22	23

2. Wheel power data $B_{20}E_5$+1.5%TWEEN 80 (KW)

Table.4.4.Wheel power B20E5+1.5%TWEEN 80 (KW)

V. Speed(km/hr)	1st gear	2nd gear	3rd gear	4th gear
25	33	29	18	11
35	31	35	24	15
45		39	29.5	21
55		31.5	37.5	29
65			29	34
75			24	24
85			20	21

3. Wheel power data $B_{20}E_{10}$+3%TWEEN 80

Table 4.5 Wheel power $B_{20}E_{10}$+3%TWEEN80

V. Speed(km/hr)	1st gear	2nd gear	3rd gear	4th gear
25	31.2	26.4	16.15	8.7
35	28.8	32.175	22.1	13.05
45		37.125	26.78	19.14
55		29.7	36.14	26.97
65			27.3	32.19
75			22.525	20.88
85			17	19.14

4. Wheel power $B_{20}E_{15}$+4.5%TWEEN 80

Table.4.6 Wheel power $B_{20}E_{15}$+4.5%TWEEN 80

V. Speed(km/hr)	1st gear	2nd gear	3rd gear	4th gear
25	28.8	23.1	14.025	6.96
35	27.2	30.1125	19.975	11.31
45		35.0625	23.8	16.53
55		27.6375	33.575	24.36
65			25.5	29.58
75			19.975	19.14
85			14.875	16.53

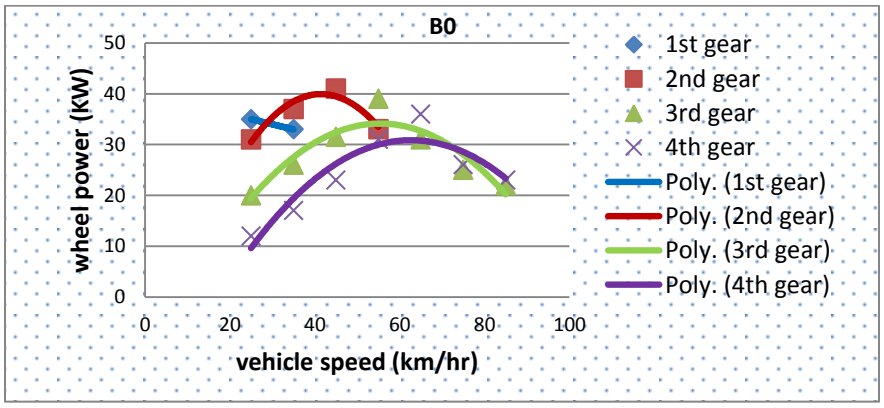

Fig.4.1 Wheel power for B_0 (KW)

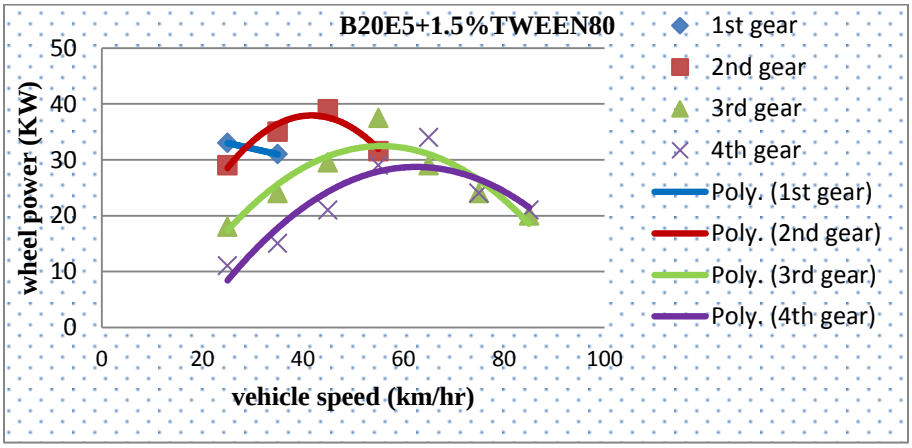

Fig.4.2.Wheel power for $B_{20}E_5$+1.5%TWEEN 80 (KW)

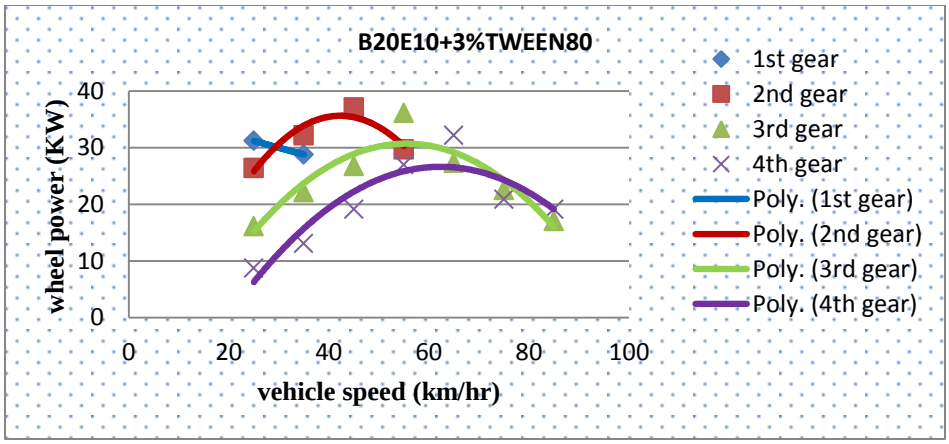

Fig.4.3.Wheel power for $B_{20}E_{10}$+3%TWEEN 80 (KW)

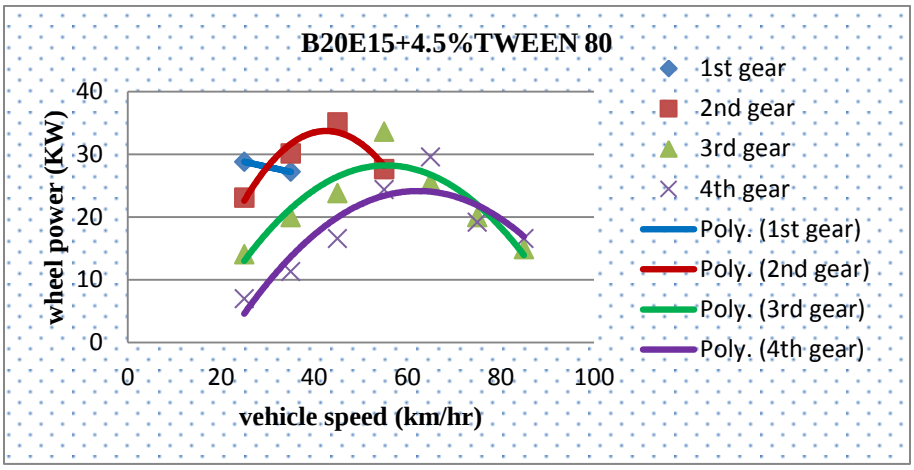

Fig.4.4. Wheel power for $B_{20}E_{15}$+4.5%TWEEN 80 (KW)

4.4.2. Tractive effort data and their graphs

1. Tractive effort data for B_0 (KN)

Table.4.7.Tractive effort for B_0 (KN)

V. Speed(km/hr)	1st gear	2nd gear	3rd gear	4th gear
25	3.8	3.6	2.25	1.3
35	1.7	2.9	2.4	1.3
45		2.5	2.4	1.5
55		1.35	1.7	1.55
65			1.25	1.3
75			0.9	1.2
85			0.85	1.1

2. Tractive effort data for $B_{20}E_5$+1.5%TWEEN 80 (KN)

Table.4.8. Tractive effort data for $B_{20}E_5$+1.5%TWEEN80 (KN)

V. Speed(km/hr)	1st gear	2nd gear	3rd gear	4th gear
25	3.68	3.475	2.13	1.1
35	1.58	2.75	2.2	1.13
45		2.35	2.15	1.3
55		1.23	1.55	1.35
65			1.05	1.1
75			0.75	1
85			0.65	0.9

3. Tractive effort data for $B_{20}E_{10}$+3%TWEEN80 (KN)

Table.4.9. Tractive effort data for $B_{20}E_{10}$+3%TWEEN80 (KN)

V. Speed(km/hr)	1st gear	2nd gear	3rd gear	4th gear
25	3.58	3.375	2.03	1
35	1.48	2.65	2.1	1.1
45		2.25	2.05	1.2
55		1.13	1.45	1.25
65			1	1
75			0.675	0.9
85			0.575	0.85

4. Tractive effort data for $B_{20}E_{15}$+4.5%TWEEN 80 (KN)

Table.4.10. Tractive effort data for $B_{20}E_{15}$+4.5%TWEEN80 (KN)

V. Speed(km/hr)	1st gear	2nd gear	3rd gear	4th gear
25	3.48	3.35	2	0.95
35	1.38	2.55	1.95	1
45		2.23	2.1	1.1
55		1.11	1.35	1.15
65			0.9	0.95
75			0.65	0.85
85			0.55	0.7

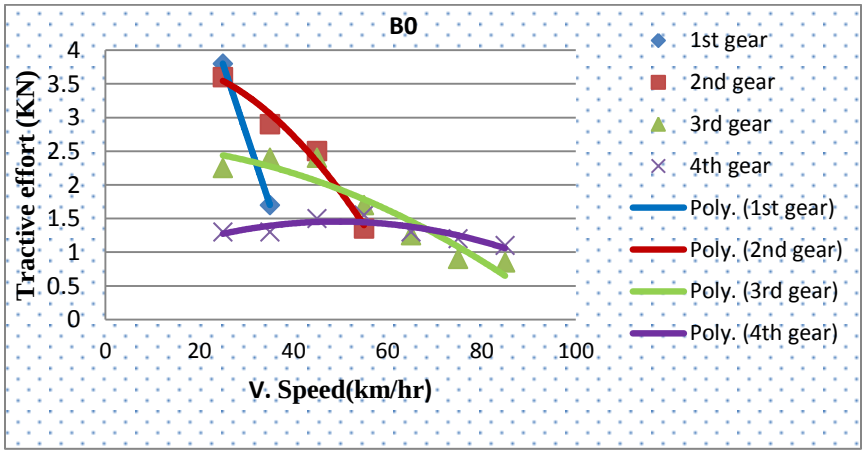

Fig.4.5. Tractive effort for B_0 (KN)

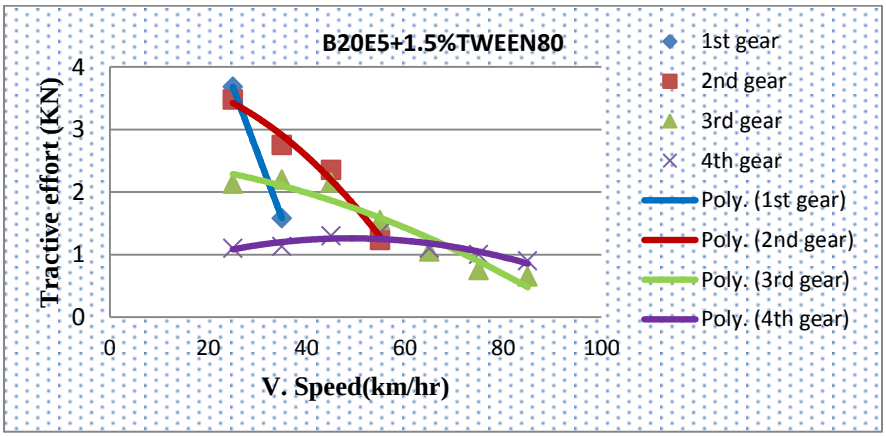

Fig.4.6.Tractive effort for $B_{20}E_5$+1.5%TWEEN80

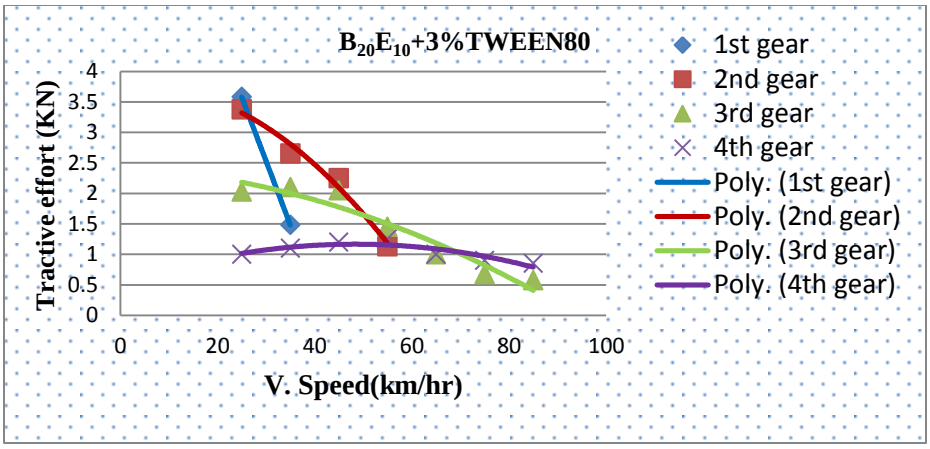

Fig4.7.Tractive effort for $B_{20}E_{10}$+3TWEEN80

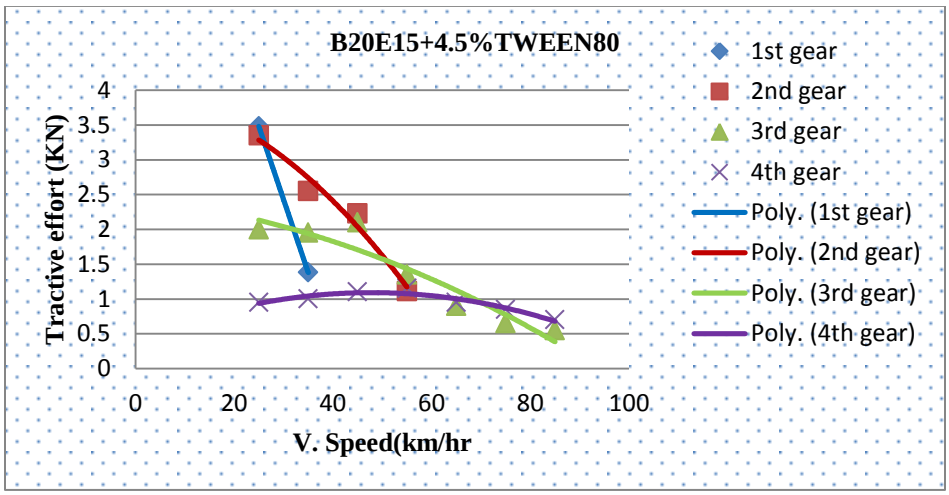

Fig.4.8.Tractive effort for $B_{20}E_{15}$+4.5%TWEEN80 (KN)

From the graph of wheel power and tractive effort we can see that power is reduced as the vehicle speed increases. This due to lower heating value of cotton biodiesel as well as additive ethanol. In the 1st gear box for both cases only two speeds considered. Due to this reason 1st gear box data seems line graph but it was not

4.4.3. Wheel torque calculation

The engine brake torque and brake power are calculated by using the measured wheel power & wheel torque from chassis dynamometer found in automotive lab of ASTU. Then the brake specific fuel consumption is calculated by measuring the fuel flow ratio.

Table4.11.wheel torque for B_0 & $B_{20}E_5$+1.5%TWEEN80

V. S (km/hr)	1st gear		2nd gear		3rd gear		4th gear	
	B_0	$B_{20}E_5$+1.5TW80	B_0	$B_{20}E_5$+1.5TW80	B_0	$B_{20}E_5$+1.5TW80	B_0	$B_{20}E_5$+1.5TW80
25	1368	1324.8	1296	1251	810	766.8	468	396
35	612	568.8	1044	990	864	792	468	406.8
45			900	846	864	774	540	468
55			486	442.8	612	558	558	486
65					450	378	468	396
75					324	270	432	360
85					306	234	396	324

Table.4.12.wheel torque for $B_{20}E_{10}$+3%TWEEN80

$B_{20}E_{10}$+3%TWEEN80				
V. S (km/hr)	1st gear	2nd gear	3rd gear	4th gear
25	1288.8	1215	730.8	360
35	532.8	954	756	396
45		810	738	432
55		406.8	522	450
65			360	360
75			243	324
85			207	306

Table.4.13. wheel torque for $B_{20}E_{15}$+4.5% TWEEN80

$B_{20}E_{15}$+4.5%TWEEN80				
V. S (km/hr)	1st gear	2nd gear	3rd gear	4th gear
25	1252.8	1206	720	342
35	496.8	918	702	360
45		802.8	756	396
55		399.6	486	414
65			324	342
75			234	306
85			198	252

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 b/n engine revolution (N) & vehicle seed can be related with the following expression.

$$N = \frac{2.65 \times V \times g_r \times a_r}{r_w} \quad (4.3)$$

Where; N =engine speed (rpm), g_r=gear box ratio,V =vehicle speed (km/hr),

a_r =axle ratio and r_w =wheel radius taken as 0.36

Table4.14. gear box, gear ratio & transmission efficiency for Toyota Hilux [Source:- http://en.wikepidia.org/wiki/Toyota transmission]

gear	1st	2nd	3rd	4th	5th	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

4.4.4. Brake Power (P_b) calculation

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 ($\mathbf{P_b}$) and is given by, $\mathbf{P_b = \frac{2\pi NT}{60}}$ **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:-

$$P_b = \frac{P_w}{\eta_t} \quad (4.4)$$

Where: - P_b-brake power, P_w- Wheel power and η_t- gear box efficiency

1. Brake power data for B_0 (KW)

Table.4.15. Brake power for B_0

V. Speed (km/hr)	1st gear		2nd gear		3rd gear		4th gear	
	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)
25	2576.4	43.75	1516.38	37.56	1060	23.53	736.11	13.79
35	3606.94	41.24	2122.94	44.85	1484	30.59	1030.56	19.54
45			2729.5	49.697	1908	37.1	1325	26.44
55			3336.05	40	2332	45.89	1619.444	35.63
65					2756	36.47	1913.88	41.38
75					3180	29.41	2208.33	29.88
85					3604	25.88	2502.78	26.44

2. Brake power data for $B_{20}E_5$+1.5%TWEEN 80 (KW)

Table.4.16.Brake power for $B_{20}E_5$+1.5%TWEEN 80 (KW)

V. Speed (km/hr)	1st gear		2nd gear		3rd gear		4th gear	
	N r(rpm)	Pb (KW)	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)
25	2576.4	41.25	1516.38	35.1515	1060	21.1765	736.11	12.6437
35	3606.94	38.75	2122.94	42.4242	1484	28.2353	1030.56	17.2414
45			2729.5	47.2727	1908	34.7059	1325	24.1379
55			3336.05	38.1818	2332	44.1176	1619.444	33.3333
65					2756	34.1176	1913.88	39.0805
75					3180	28.2353	2208.33	27.5862
85					3604	23.5294	2502.78	24.1379

3. Brake power data for $B_{20}E_{10}$+3%TWEEN 80

Table.4.17.Brake power for B20E10+3%TWEEN 80

V. S (km/hr)	1st gear		2nd gear		3rd gear		4th gear	
	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)
25	2576.4	39	1516.38	32	1060	19	736.11	10
35	3606.94	36	2122.94	39	1484	26	1030.56	15
45			2729.5	45	1908	31.5	1325	22
55			3336.05	36	2332	42.5176	1619.444	31
65					2756	32.1176	1913.88	37
75					3180	26.5	2208.33	24
85					3604	20	2502.78	22

4. Brake power data for $B_{20}E_{15}$+4.5%TWEEN 80

Table.4.18.Brake power for $B_{20}E_{15}$+4.5%TWEEN 80

V. S (km/hr)	1st gear		2nd gear		3rd gear		4th gear	
	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)	N (rpm)	Pb (KW)
25	2576.4	36	1516.38	28	1060	16.5	736.11	8
35	3606.94	34	2122.94	36.5	1484	23.5	1030.56	13
45			2729.5	42.5	1908	28	1325	19
55			3336.05	33.5	2332	39.5	1619.444	28
65					2756	30	1913.88	34
75					3180	23.5	2208.33	22
85					3604	17.5	2502.78	19

Table.4.19. brake power data's of four samples

Brake power (KW)						
gear	V. S (km/hr)	N(rpm)	B_0	$B_{20}E_5$+1.5TW80	$B_{20}E_{10}$+3TW80	B20E15+4.5TW80
1st gr	25	2576.4	43.75	41.25	39	36
	35	3606.94	41.24	38.75	36	34
2nd gr	25	1516.38	37.56	35.1515	32	28
	35	2122.94	44.85	42.4242	39	36.5
	45	2729.5	49.697	47.2727	45	42.5
	55	3336.05	40	38.1818	36	33.5
3rd gr	25	1060	23.53	21.1765	19	16.5
	35	1484	30.59	28.2353	26	23.5
	45	1908	37.1	34.7059	31.5	28
	55	2332	45.89	44.1176	42.5176	39.5
	65	2756	36.47	34.1176	32.1176	30
	75	3180	29.41	28.2353	26.5	23.5
	85	3604	25.88	23.5294	20	17.5
4th gr	25	736.11	13.79	12.6437	10	8
	35	1030.56	19.54	17.2414	15	13
	45	1325	26.44	24.1379	22	19
	55	1619.44	35.63	33.3333	31	28
	65	1913.88	41.38	39.0805	37	34
	75	2208.33	29.88	27.5862	24	22
	85	2502.78	26.44	24.1379	22	19

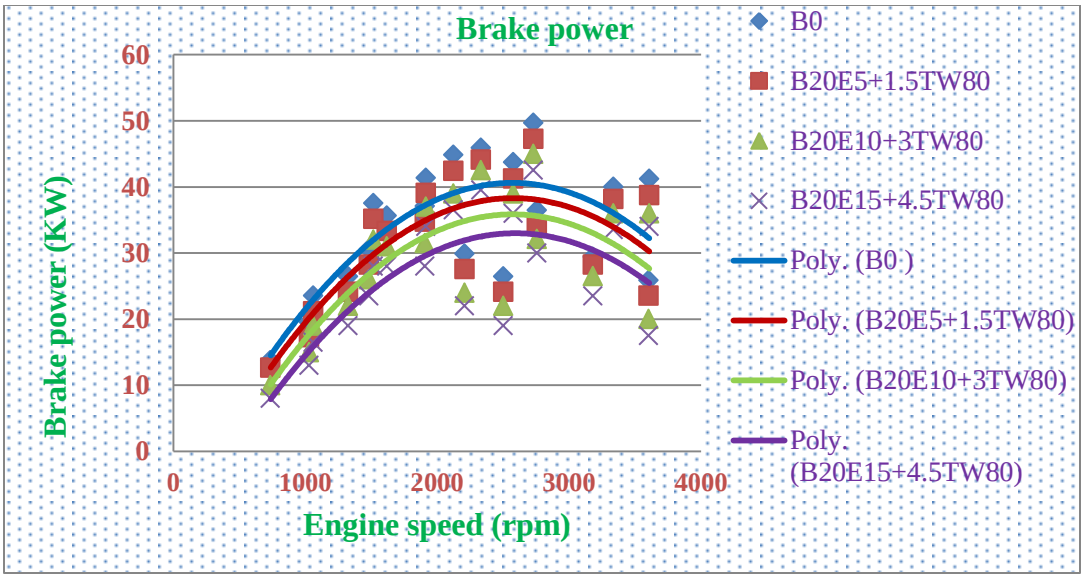

Fig.4.9.variation of brake power with respect to engine speed

It can be seen that from the figure 4.9 that the biodiesel blends with ethanol as additive fuels produced lower brake power than diesel fuel. Brake power increases with increasing engine speed unti2729.5rpm and then power starts to decrease. In case of biodiesel blended fuels $B_{20}E_5$+1.5%TW80, $B_{20}E_{10}$+3%TW80, & $B_{20}E_{15}$+4.5%TW80 the average reduction of brake power is by 4.9%, 9.5% & 14.5% 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 added with ethanol is needed to produce equivalent power output as compared to diesel.

4.4.5. Brake torque (T_b) calculation

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

Its unit is in 'Nm'

$$\mathbf{P_b}=\frac{2\pi NT}{60}$$

$$T_b={P_b}/{\omega}=\frac{60\times P_b}{2\pi\times N} \qquad (4.5)$$

$$T_b=\frac{60\times P_b\times 1000}{2\pi\times N}$$ **Where** P_b is 'KW', N is in 'rpm' & T_b is in 'Nm'

1. Brake torque (T_b) data for B_0 (N.m)

Table.4.20.Brake torque (T_b) for B_0

V. Speed (km/hr)	1st gear		2nd gear		3rd gear		4th gear	
	N @1st gr(rpm)	T_b @1st gr (Nm)	N @2nd gr (rpm)	T_b @ 2nd gr (Nm)	N @ 3rd gr (rpm)	T_b @ 3rd gr (Nm)	N @ 4th gr (rpm)	T_b @ 4th gr (Nm)
25	2576.4	162.16	1516.38	236.53	1060	211.98	736.11	178.89
35	3606.94	109.18	2122.94	201.74	1484	196.84	1030.56	181.1
45			2729.5	173.87	1908	185.68	1325	190.55
55			3336.05	114.5	2332	187.92	1619.444	206.38
65					2756	126.37	1913.88	206.47
75					3180	88.32	2208.33	129.21
85					3604	68.1	2502.78	100.88

2. Brake torque (T_b) data for $B2_0E_5$+1.5%TWEEN80 (N.m)

Table.4.21.Brake torque (T_b) for $B_{20}E_5$+1.5%TWEEN 80(N.m)

V. Speed (km/hr)	1st gear		2nd gear		3rd gear		4th gear	
	N @1st gr(rpm)	T_b @1st gr (N.m)	N @2nd gr (rpm)	T_b @ 2nd gr (Nm)	N @ 3rd gr (rpm)	T_b @ 3rd gr (N.m)	N @ 4th gr (rpm)	T_b @ 4th gr (N.m)
25	2576.4	152.89	1516.38	221.6	1060	190	736.11	163.97
35	3606.94	102.6	2122.94	190	1484	181.72	1030.56	159.5
45			2729.5	165.5	1908	173.2	1325	173.97
55			3336.05	109.35	2332	180.67	1619.444	196.5
65					2756	118.2	1913.88	195.1
75					3180	84.8	2208.33	119.3
85					3604	62.35	2502.78	92.11

3. Brake torque (T_b) data for $B_{20}E_{10}$+3%TWEEN 80

Table.4.22.Brake torque (T_b) for $B_{20}E_{10}$+3%TWEEN 80

V.S (km/hr)	1st gear		2nd gear		3rd gear		4th gear	
	N @1st gr(rpm)	T_b @1st gr (Nm)	N @2nd gr(rpm)	T_b @ 2nd gr (Nm)	N @ 3rd gr (rpm)	T_b @ 3rd gr (Nm)	N @ 4th gr (rpm)	T_b @ 4th gr (Nm)
25	2576.4	144.5	1516.38	201.52	1060	171.2	736.11	129.73
35	3606.94	95.3	2122.94	175.43	1484	167.31	1030.56	138.99
45			2729.5	157.4	1908	157.65	1325	158.6
55			3336.05	103	2332	174.1	1619.444	182.79
65					2756	111.3	1913.88	184.6
75					3180	78	2208.33	103.8
85					3604	52.9	2502.78	83.94

4. Brake torque (T_b) data for $B_{20}E_{15}$+4.5%TWEEN 80

Table.4.23.Brake torque (T_b) for B20E15+4.5%TWEEN 80

V. S (km/hr)	1st gear		2nd gear		3rd gear		4th gear	
	N @1st gr(rpm)	T_b @1st gr (Nm)	N @2nd gr (rpm)	T_b @ 2nd gr (Nm)	N @ 3rd gr (rpm)	T_b @ 3rd gr (Nm)	N @ 4th gr (rpm)	T_b @ 4th gr (Nm)
25	2576.4	133.4	1516.38	176.32	1060	148.6	736.11	103.78
35	3606.94	90	2122.94	164.2	1484	151.22	1030.56	120.5
45			2729.5	148.7	1908	140.14	1325	136.93
55			3336.05	95	2332	161.75	1619.444	165.11
65					2756	103	1913.88	169.6
75					3180	70.57	2208.33	95.13
85					3604	120.71	2502.78	72.5

Table.4.24.Brake torque (T_b) of four samples

gear	V. S (km/hr)	N(rpm)	B0	B20E5+1.5TW80	B2010+3TW80	B20E15+4.5TW80
1st gr	25	2576.4	162.16	152.89	144.5	133.4
	35	3606.94	109.18	102.6	95.3	90
2nd gr	25	1516.38	236.53	221.6	201.52	176.32
	35	2122.94	201.74	190	175.43	164.2
	45	2729.5	173.87	165.5	157.4	148.7
	55	3336.05	114.5	109.35	103	95
3rd gr	25	1060	211.98	190	171.2	148.6
	35	1484	196.84	181.72	167.31	151.22
	45	1908	185.68	173.2	157.65	140.14
	55	2332	187.92	180.67	174.1	161.75
	65	2756	126.37	118.2	111.3	103
	75	3180	88.32	84.8	78	70.57
	85	3604	68.8	62.35	52.9	45
4th gr	25	736.11	178.89	163.97	129.73	103.78
	35	1030.56	181.1	159.5	138.99	120.5
	45	1325	190.55	173.97	158.6	136.93
	55	1619.44	206.38	196.5	182.79	165.11
	65	1913.88	206.47	195.1	184.6	169.6
	75	2208.33	129.21	119.3	103.8	95.13
	85	2502.78	100.88	92.11	83.94	72.5

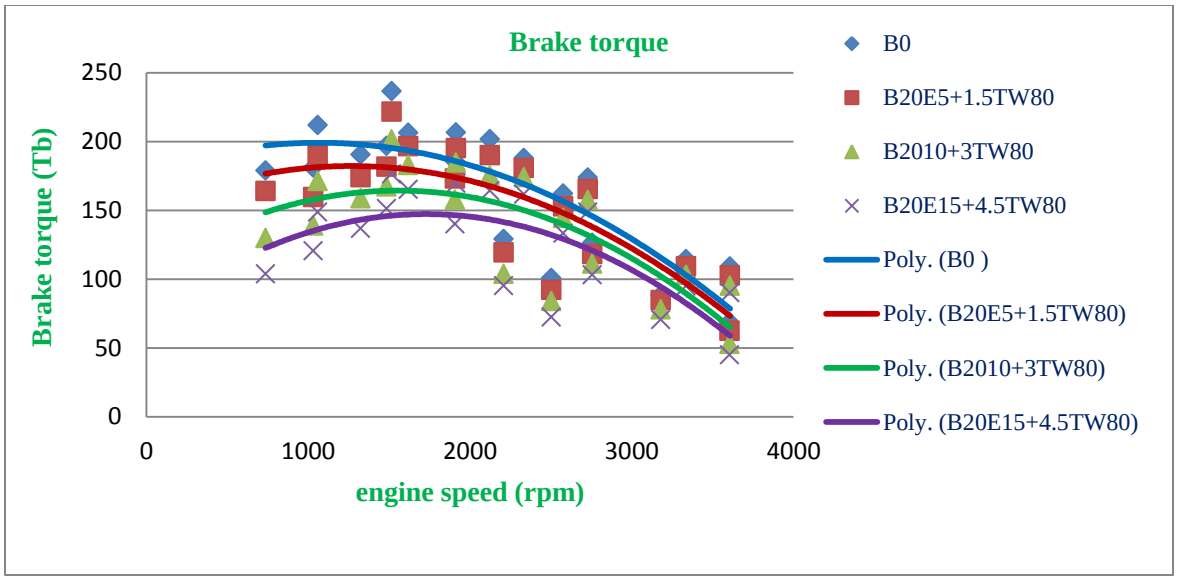

Fig.4.10.variation of brake torque with respect to engine speed

Brake torque initially increases with increasing of engine speed until it reaches 1516.38 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 with additive ethanol. The reason for the reduction of torque with blends can be the lower heating value of the fuel and ethanol. For all blended test fuels the average torque reduction compared to diesel fuel is by 6.3%, 14.62% & 25% on average respectively.

4.4.6. Fuel consumptions

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/hr)'to develop a brake power (Pb) 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 fuel economy of the engine.

$$\text{Specific fuel consumption (SFC)} = \frac{\text{mass flow rate}}{\text{power}}$$

Brake specific fuel consumption (BSFC) $=\frac{\text{mass flow rate}}{\text{brake power}}$ 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.

$mf=\rho \times \tilde{V}$ (4.6)

Where: - mf=mass flow rate (gm/sec), $\tilde{V}$ =volume flow rate (ml/sec) and

ρ =Density of the fuel (gm/ml)

$(\text{BSFC} = \frac{\text{mf}\left(\frac{\text{gm}}{\text{se}}\right)\times 3600}{\text{brake power}}\left(\frac{\text{gm}}{\text{kwhr}}\right)$

$\text{BSFC} = \frac{\text{mf}\left(\frac{\text{gm}}{\text{se}}\right)\times 3600}{P_b}\left(\frac{\text{gm}}{\text{kwhr}}\right)$ (4.7)

Fuel Consumption and mass flow rate of **B_0 ($\rho = 0.852$)**

The fuel consumption data for samples measured in automotive workshop.

1. Fuel Consumption calculation of B_0

Table.4.25. Fuel Consumption & flow rate of B_0

V.S (Km/hr)	Fuel Consumption (cm^3/sec) of **B_0, $\rho = 0.852$**							
	1st gear		2nd gear		3rd gear		4th gear	
	V (cm^3/se)	mf (gm/sec)	V (cm^3/se)	mf (gm/sec)	V (cm^3/se)	mf (gm/sec)	V (cm^3/se)	mf (gm/sec)
25	4.2	3.5784	3.7	3.1524	2.4	2.0448	1.7	1.4484
35	4.8	4.0896	4.5	3.834	3.1	2.6412	2	1.704
45			5.3	4.5156	3.5	2.982	2.4	2.0448
55			5.7	4.8564	4	3.408	2.9	2.4708
65					4.4	3.7488	3.5	2.982
75					4.6	3.9192	4.1	3.4932
85					4.8	4.0896	4.6	3.9192

2. Fuel Consumption calculation of $B_{20}E_5$+1.5%TWEEN80

Table.4.26. Fuel Consumption & flow rate of $B_{20}E_5$+1.5%TWEEN80

V.S (Km/hr)	Fuel Consumption (cm^3/sec) of $B_{20}E_5$+1.5%TWEEN80, $\rho = 0.856 = (0.8577@15℃ + 0.8542@20℃)/2$							
	1st gear		2nd gear		3rd gear		4th gear	
	V (cm^3/sec)	mf (gm/sec)	V (cm^3/sec)	mf (gm/sec)	V (cm^3/sec)	mf (gm/sec)	V (cm^3/sec)	mf (gm/sec)
25	4.5	3.852	3.9	3.3384	2.7	2.3112	2	1.712
35	5.1	4.3656	4.8	4.1088	3.4	2.9104	2.4	2.0544
45			5.6	4.7936	3.8	3.2528	2.7	2.3112
55			6.1	5.2216	4.45	3.8092	3.3	2.8248
65					4.8	4.1088	3.8	3.2528
75					4.9	4.1944	4.4	3.7664
85					5.3	4.5368	5	4.28

3. Fuel Consumption calculation of $B_{20}E_{10}$+3%TWEEN80

Table.4.27. Fuel Consumption & flow rate of $B_{20}E_{10}$+3%TWEEN80

V.S (Km/hr)	Fuel Consumption (cm^3/sec) of $B_{20}E_{10}$+3%TWEEN80, $\rho = 0.855 = (0.8563@15℃+0.8528@20℃)/2$							
	1st gear		2nd gear		3rd gear		4th gear	
	V (cm^3/se)	mf (gm/sec)	V (cm^3/se)	mf (gm/sec)	V (cm^3/se)	mf (gm/sec)	V (cm^3/se)	mf (gm/sec)
25	4.7	4.0185	4.1	3.5055	2.95	2.52225	2.25	1.92375
35	5.3	4.5315	5	4.275	3.65	3.12075	2.6	2.223
45			5.8	4.959	4	3.42	2.9	2.4795
55			6.3	5.3865	4.65	3.97575	3.5	2.9925
65					5	4.275	4	3.42
75					5.3	4.5315	4.65	3.97575
85					5.55	4.74525	5.3	4.5315

4. Fuel Consumption calculation of $B_{20}E_{15}$+4.5%TWEEN80

Table.4.28. Fuel Consumption & flow rate of $B_{20}E_{15}$+4.5%TWEEN80

V.S (Km/hr)	Fuel Consumption (cm^3/sec) of $B_{20}E_{15}$+4.5%TWEEN 80, **0.853 = (** 0.8548@15℃ + 0.8513@20℃**)/2**							
	1st gear		2nd gear		3rd gear		4th gear	
	V (cm^3/sec)	mf (gm/sec)	V (cm^3/sec)	mf (gm/sec)	V (cm^3/sec)	mf (gm/sec)	V (cm^3/sec)	mf (gm/sec)
25	4.95	4.22235	4.3	3.6679	3.2	2.7296	2.45	2.08985
35	5.5	4.6915	5.2	4.4356	3.9	3.3267	2.85	2.43105
45			6.1	5.2033	4.25	3.62525	3.2	2.7296
55			6.55	5.58715	4.85	4.13705	3.7	3.1561
65					5.2	4.4356	4.2	3.5826
75					5.5	4.6915	4.8	4.0944
85					5.75	4.90475	5.6	4.7768

Table.4.29.pb, mf and BSFC of four samples with respect to engine speed

N (rpm)	B_0			B20E5+1.5TW80			B2010+3TW80			B20E15+4.5TW80		
	pb	mf	BSFC	pb	mf	BSFC	pb	mf	BSFC	pb	mf	BSFC
2576.4	43.75	3.58	294.5	41.25	3.85	336.2	39	4.02	371	36	4.22	422.24
3606.94	41.24	4.09	357	38.75	4.37	405.6	36	4.53	453.2	34	4.69	496.75
1516.38	37.56	3.15	302.15	35.2	3.34	341.43	32	3.51	394.4	28	3.67	471.59
2122.94	44.85	3.83	307.75	42.42	4.11	348.7	39	4.28	394.62	36.5	4.44	437.5
2729.5	49.7	4.52	327.11	47.3	4.79	365.1	45	4.96	396.72	42.5	5.20	440.75
3336.05	40	4.86	437.1	38.2	5.22	492.1	36	5.39	538.65	33.5	5.59	600.41
1060	23.53	2.045	312.85	21.2	2.31	392.5	19	2.52	477.9	16.5	2.73	595.6
1484	30.59	2.64	310.83	28.24	2.91	371.1	26	3.12	432.1	23.5	3.33	509.62
1908	37.1	2.98	289.36	34.71	3.25	337.37	31.5	3.42	390.86	28	3.63	466.1
2332	45.89	3.41	267.35	44.12	3.81	310.8	42.52	3.97	336.6	39.5	4.14	377.1
2756	36.47	3.75	370.05	34.12	4.11	433.52	32.12	4.275	479.14	30	4.44	532.3
3180	29.41	3.92	479.74	28.24	4.19	534.786	26.5	4.53	615.6	23.5	4.69	718.7
3604	25.88	4.09	568.88	23.53	4.54	694.13	20	4.75	854.15	17.5	4.91	1009
736.11	13.79	1.45	378.12	12.64	1.712	487.45	10	1.92	692.6	8	2.09	940.4
1030.56	19.54	1.704	313.94	17.24	2.054	428.96	15	2.22	533.52	13	2.43	673.2
1325	26.44	2.05	278.41	24.14	2.31	344.7	22	2.48	405.74	19	2.73	517.19
1619.44	35.63	2.5	249.65	33.33	2.83	305	31	2.99	347.52	28	3.16	405.78
1913.88	41.38	2.98	259.43	39.1	3.253	299.64	37	3.42	332.76	34	3.59	379.4
2208.33	29.88	3.5	420.87	27.59	3.77	491.52	24	3.98	596.4	22	4.1	670
2502.78	26.44	3.92	533.63	24.14	4.28	638.28	22	4.53	741.52	19	4.78	905.1

Table.4.30.bsfc of four samples of B_0, $B_{20}E_5$+1.5%TWEEN80, $B_{20}E_{10}$+3%TWEEN80 & $B_{20}E_{15}$+4.5%TWEEN80

BSFC (gm/KWhr)				
N(rpm)	B_0	$B_{20}E_5$+1.5%TWEEN80	$B_{20}E_{10}$+3%TWEEN80	$B_{20}E_{15}$+4.5%TWEEN80
2576.4	294.5	336.2	371	422.24
3606.94	357	405.6	453.2	496.75
1516.38	302.15	341.43	394.4	471.59
2122.94	307.75	348.7	394.62	437.5
2729.5	327.11	365.1	396.72	440.75
3336.05	437.1	492.1	538.65	600.41
1060	312.85	392.5	477.9	595.6
1484	310.83	371.1	432.1	509.62
1908	289.36	337.37	390.86	466.1
2332	267.35	310.8	336.6	377.1
2756	370.05	433.52	479.14	532.3
3180	479.74	534.786	615.6	718.7
3604	568.88	694.13	854.15	1009
736.11	378.12	487.45	692.6	940.4
1030.56	313.94	428.96	533.52	673.2
1325	278.41	344.7	405.74	517.19
1619.44	249.65	305	347.52	405.78
1913.88	259.43	299.64	332.76	379.4
2208.33	420.87	491.52	596.4	670
2502.78	533.63	638.28	741.52	905.1

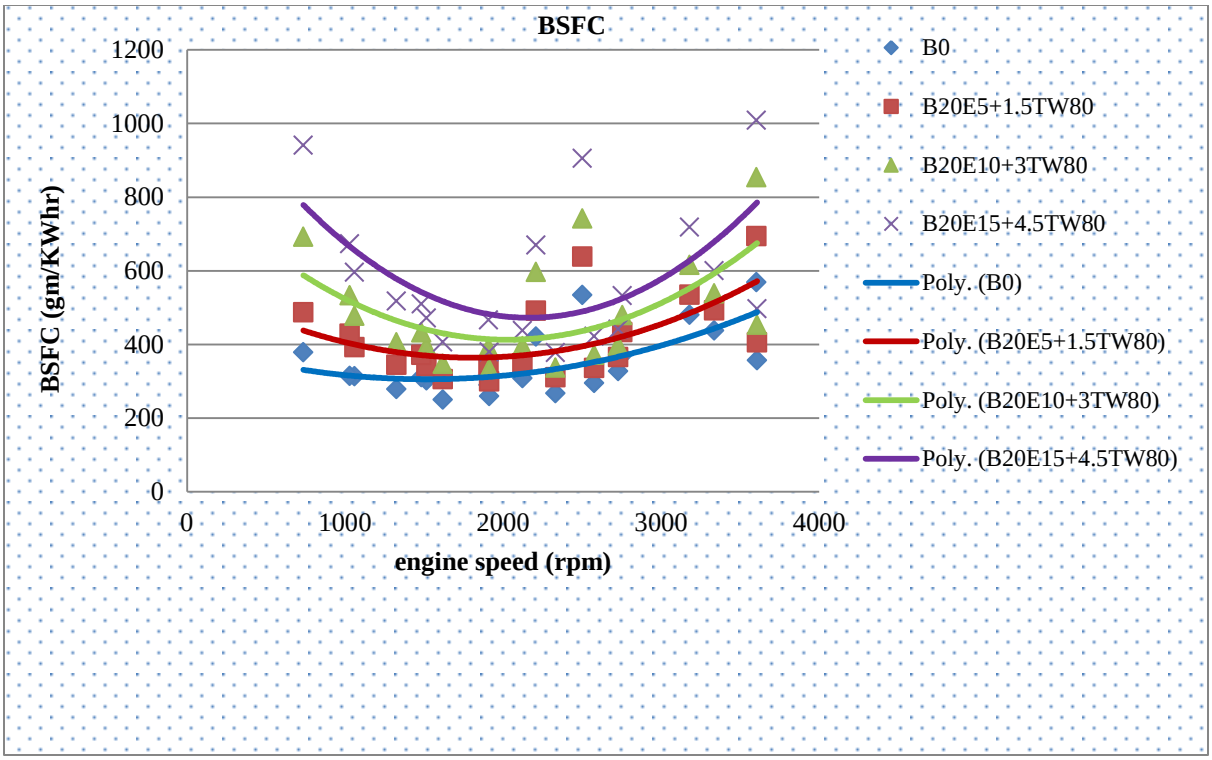

Fig.4.11.Variation of BSFC with engine speed

From the above figure, we can see that diesel fuel had the lowest BSFC and the BSFC of blends of B_{20} With additive ethanol is increasing as the percentage of ethanol increases and become more for $B_{20}E_{15}$ than the other two samples of biodiesel with additive blended. This is due to the lower heating values of ethanol and biodiesel when compared to pure diesel. The average BSFC increment for biodiesel with additive is 15.5%, 23.5% and 29.9% respectively for $B_{20}E_5$, $B_{20}E_{10}$ & $B_{20}E_{15}$ with reference of diesel fuel.

4.4.7. Engine performance calculated data and curves

Performance curves of B_0

Using scale the performance curve is as follow.

Table.4.31.Performance of B_0

Performance of B_0			
scales			
1:01	01:00.5	1:02	1:25
N(rpm)	Pb	T_b	BSFC
2576.4	87.5	81.08	11.78
3606.94	82.48	54.59	14.28
1516.38	75.12	118.265	12.086
2122.94	89.7	100.87	12.31
2729.5	99.394	86.935	13.0844
3336.05	80	57.25	17.484
1060	47.06	105.99	12.514
1484	61.18	98.42	12.4332
1908	74.2	92.84	11.5744
2332	91.78	93.96	10.694
2756	72.94	63.185	14.802
3180	58.82	44.16	19.1896
3604	51.76	34.4	22.7552
736.11	27.58	89.445	15.1248
1030.56	39.08	90.55	12.5576
1325	52.88	95.275	11.1364
1619.44	71.26	103.19	9.986
1913.88	82.76	103.235	10.3772
2208.33	59.76	64.605	16.8348
2502.78	52.88	50.44	21.3452

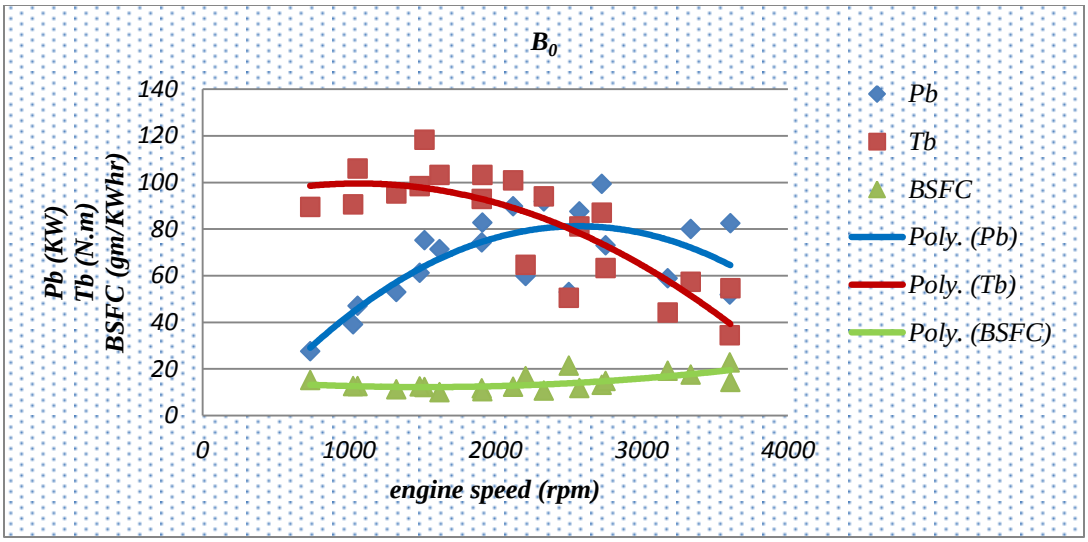

Fig.4.12. Performance of B_0

Table.4.32.Performance of B_0E_5+1.5%TWEEN80

Performance of B_0E_5+1.5%TWEEN80			
1:01	01:00.5	1:02	1:25
N(rpm)	Pb	T_b	BSFC
2576.4	82.5	76.445	13.448
3606.94	77.5	51.3	16.224
1516.38	70.303	110.8	13.6572
2122.94	84.8484	95	13.948
2729.5	94.5454	82.75	14.604
3336.05	76.3636	54.675	19.684
1060	42.353	95	15.7
1484	56.4706	90.86	14.844
1908	69.4118	86.6	13.4948
2332	88.2352	90.335	12.432
2756	68.2352	59.1	17.3408
3180	56.4706	42.4	21.39144
3604	47.0588	31.175	27.7652
736.11	25.2874	81.985	19.498
1030.56	34.4828	79.75	17.1584
1325	48.2758	86.985	13.788
1619.44	66.6666	98.25	12.2
1913.88	78.161	97.55	11.9856
2208.33	55.1724	59.65	19.6608
2502.78	48.2758	46.055	25.5312

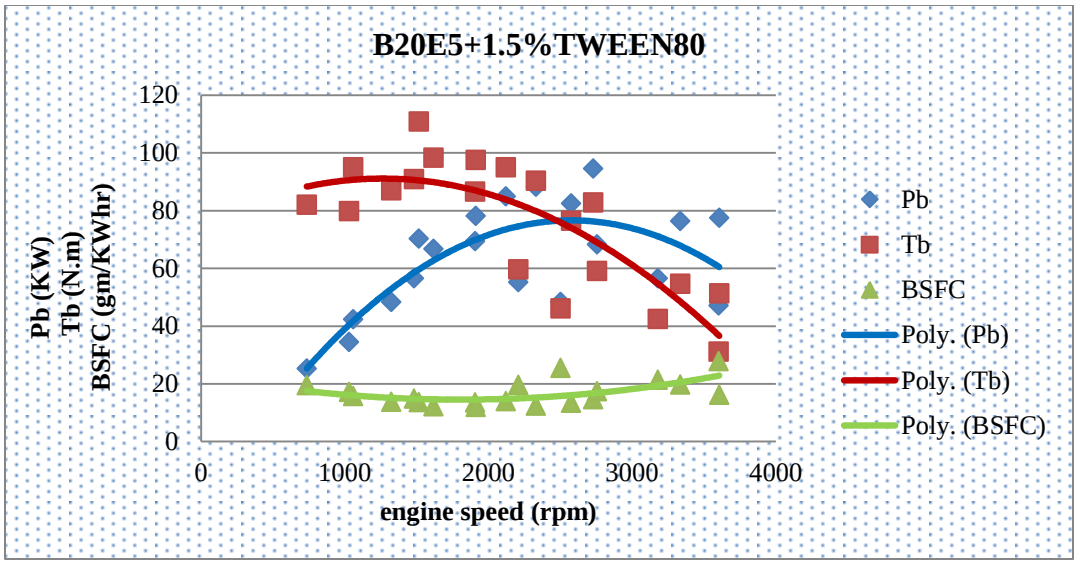

Fig.4.13. Performance of B_0E_5+1.5%TWEEN80

Table.4.33.Performance of B_0E_{10}+3%TWEEN80

Performance of B_0E_{10}+3%TWEEN80			
1:01	01:00.5	1:02	1:25
N(rpm)	Pb	T_b	BSFC
2576.4	78	72.25	14.844
3606.94	72	47.65	18.12
1516.38	64	100.76	15.7952
2122.94	78	87.715	15.8768
2729.5	90	78.7	15.86
3336.05	72	51.5	21.6
1060	38	85.6	19.108
1484	52	83.655	17.28
1908	63	78.825	15.6344
2332	85.0352	87.05	13.46
2756	64.2352	55.65	19.2776
3180	53	39	24.616
3604	40	26.45	34.128
736.11	20	64.865	27.648
1030.56	30	69.495	213.12
1325	44	79.3	16.2328
1619.44	62	91.395	13.8892
1913.88	74	92.3	13.3104
2208.33	48	51.9	23.844
2502.78	44	41.97	29.652

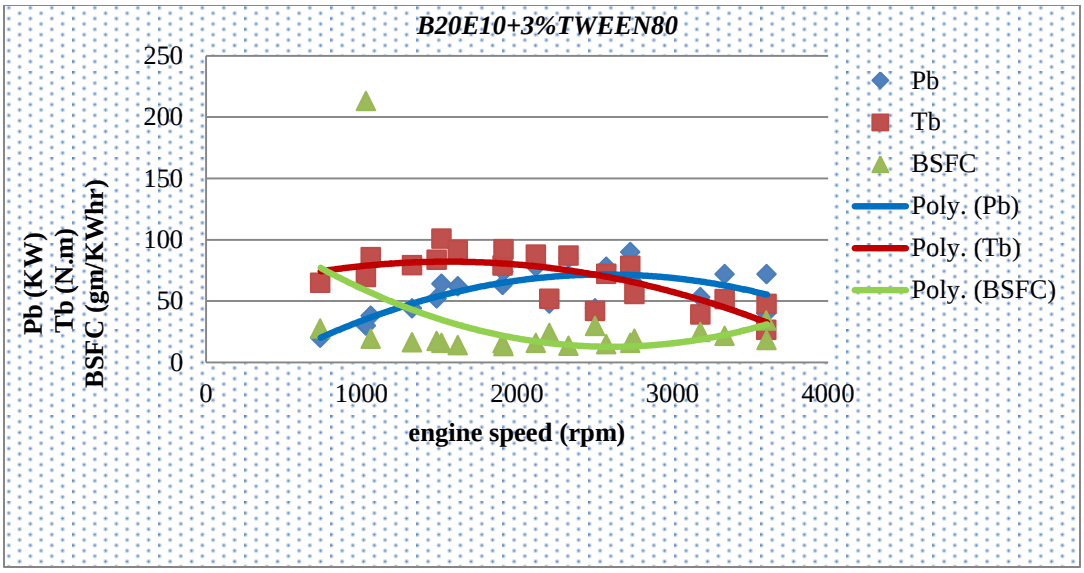

Fig.4.14 Performance of B_0E_{10}+3%TWEEN80

Table.4.34.Performance of B_0E_{15}+4.5%TWEEN80

Performance of B_0E_{15}+4.5%TWEEN80			
1:01	01:00.5	1:02	1:25
N(rpm)	Pb	T_b	BSFC
2576.4	72	66.7	16.8896
3606.94	68	45	19.87
1516.38	56	88.16	18.8636
2122.94	73	82.1	17.5
2729.5	85	74.35	17.63
3336.05	67	47.5	24.0164
1060	33	74.3	23.824
1484	47	75.61	20.3848
1908	56	70.07	18.644
2332	79	80.875	15.084
2756	60	51.5	21.292
3180	47	35.285	28.748
3604	35	23.2	40.36
736.11	16	51.89	37.616
1030.56	26	60.25	26.928
1325	38	68.465	20.6876
1619.44	56	82.555	16.2312
1913.88	68	84.8	15.176
2208.33	44	47.565	26.8
2502.78	38	36.25	36.204

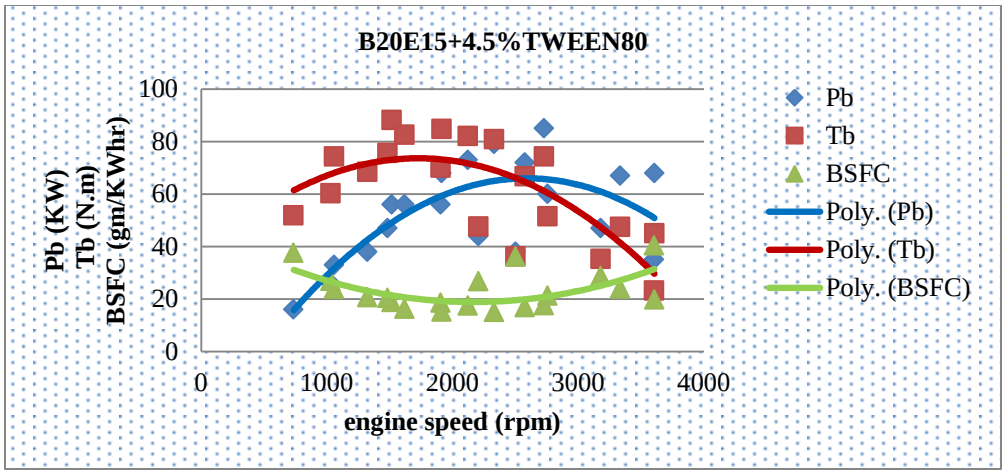

Fig.4.15. Performance of B_0E_{15}+4.5%TW80

All the above performance curve shows that the performance of the engine with B_0, B_0E_{10}+3%TWEEN80, B_0E_{10}+3%TWEEN80 and B_0E_{15}+4.5%TWDEEN80 respectively. The parameters used to compare b/n these four samples on performance test were mainly brake power, brake torque, and the fuel consumption with respect to engine speed. Due to this when the percentage of ethanol increases in the blend of B_{20} the brake power and brake torque decreases and the fuel consumption (brake specific fuel consumption) increases with increasing engine speed. This due to higher viscosity and lower heating values of biodiesel and the addition of ethanol to diesel fuel simultaneously decreases calorific value, kinematic viscosity and stability of fuel.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Different experiments were conducted in this thesis work with the aim of testing the performance of cotton biodiesel with additive ethanol in diesel vehicle Toyota 3L and for miscibility of ethanol with diesel, reagent tween 80 was used. In this research pure biodiesel was not used because its viscosity is still higher than conventional diesel fuel. Anhydrous Ethanol was used as additive for best miscibility. Small amount of tween 80 were used for stability of miscibility of ethanol with diesel then finally biodiesel was added according to proportion required for blending of $B_{20}E_5$+1.5%TWEEN80, $B_{20}E_{10}$+3%TWEEN80 & $B_{20}E_{15}$+4.5%TWEEN80. These blends were prepared for characterization as well as for performance test to study the effects of ethanol addition on biodiesel blends. From the results it is observed that engine performance when operated with the biodiesel blends with additive ethanol is comparable to that when operated/fuelled with conventional diesel fuel and most importantly the effect of ethanol addition to B_{20} were studied. The fuel consumption increases when compared to diesel and as the amount of ethanol percent for blending increases. Therefore a little more ethanol must be supplied as additive of biodiesel blend of B_{20} to the engine to produce an equivalent amount of work. In general the properties of cotton seed biodiesel and its blends conform to ASTM D6751 standards. The power and torque performance produced get reduced and the fuel consumption increased as the percentage of ethanol increased. This is due the fact that ethanol and biodiesel have lower heating value compared the conventional fuel. The results obtained in this thesis work suggests that cotton seed biodiesel blend of B_{20} can be used with additive ethanol up to tested percent increment of ethanol.in this test amount of ethanol used 5%, 10% and 15%. From this the first two are most applicable.

5.2 recommendations

The recommendations of this thesis are:-

- It is recommended to use biodiesel to save environment and foreign exchange. Government has to encourage the people in that direction
- The byproduct, the cake of the oil extraction process is a good fertilizer. So it is recommended that the farmers should use this as fertilizer adding value to this process.
- It is well known that glycerol which is obtained as a byproduct during transesterification process is a very valuable product. So it is recommended to find the ways to refine the crude glycerol obtained and use for different purpose.
- The researcher recommends usage of ethanol additive is recommended as it considerably decreases viscosity of biodiesel and improving its performance.
- Department of Mechanical engineering must establish the engine testing facilities like variable compression ratio engine with data using for future research work on alternative fuels.
- It is also recommended to conduct further research on evaluation of effect of increasing the quantity of ethanol in a given biodiesel petro diesel blend.

5.3. Future work

The present study was only focused on to evaluate the performance of cottonseed biodiesel blends of B_{20} with ethanol as additive in a four stroke diesel engine with reference of petrol diesel and determined some properties of the tested fuels. However, for the better understanding of the performance of the tested fuels other physicochemical properties of the fuels that determine the quality should be analyzed.

During the study the production of biodiesel from cotton seed oil with methanol and KOH was used through transesterification reaction. For better understanding of the biodiesel production, and to determine the optimum production parameters the transesterification reaction kinetics at different reaction parameters should be studied in detail.

Additional research has to be done emission test and analyzes 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 major problems with biodiesel.

REFERENCES

[1] Ethiopian Petroleum Enterprise Report, 2011.

[2] Alemayehu Tegenu (2007 keynote addressed by H.E. minister Alemayehu Tegenu, ministry of mines and energy , Ethiopia First high Level biofuels seminar in Africa, 30 juiy-1 August 2007 Addis Ababa.],[federal democratic republic of Ethiopia (FDRE)(2007)bio-fuel Development and utilization strategy of Ethiopia, Addis Ababa: ministry of mines and energy.

[3] A.S.A.E. Atabani, "Non-edible Vegetable Oils: A Critical Evaluation of Oil Extraction, Fatty Acid Compositions, Biodiesel Production, Characteristics, Engine Performance and Emissions Production'," Renewable and Sustainable Energy Reviews, Pp.211-245, 2013.

[4] Yanuandri Putrasari, Arifin Nur, Aam Muharam, "Performance and Emission Characteristic on a Two Cylinder DI Diesel Engine Fueled with Ethanol-Diesel Blends," in International Conference on Sustainable Energy Engineering And Application [ICSEEA 2012], Energy Procedia 32,Pp. 21-30, 2013.

[5] FDRE Ministry of Mines and Energy "The Biofuel Development & Utilization Strategy", Aug 2007.

[6] Avinash Kumar Agarwal', "Biofuels (alcohols and biodiesel) applications as fuels ford internal combustion engines," progress in energy and combustion science, 33, 200, pp233–271.

[7] Cao X. "Climate change and energy development:" implications for developing countries.Resoure Policy 2003, 2, pp. 61–7.

[8] Johansson T, McCarthy S. "Global warming post-Kyoto: continuing impasse or prospects for progress Energy Dev." Rep Energy 1999, pp. 69–71.

[9] Murphy JD, McCarthy K. "The optimal production of biogas for use as a transport fuel in Ireland." Renew Energy 2005, 30, 2111–2127.

[10] Goldemberg J, Johnsson TB, Reddy AKN, Williams RH. "Energy for the new millennium." R Swedish Sci. 2001, 30(6), 330–337.

[11] Gilbert R, Perl A. "Energy and transport futures." A report prepared for national round table on the environment and the economy, University of Calgary, June 2005. pp. 1–96.

[12] Dinesh K., Agarwal Phundan, Singh Mukta Chakrabarty, A.J. Sheikh, S.G. Gayal, "Cottonseed Oil Quality Utilization And Processing'," CICR TECHNICAL BULLETIN NO: 25.

[13] "http://cotton.tamu.edu/cottoncountry.html."

[14] "Twenty Facts about Cottonseed Oil from cotton plant." National Cottonseed Products Association. 2015-10-17.

[15] "http://www.nhm.ac.uk/resources/nature-online/life/plants-fungi/seeds-of-trade/images/maps/cotton.gif"

[16] Sadras, V.O., Wilson, L.J., 1997. "Growth analysis of cotton crops infested with spider mites .1. Light interception and radiation-use efficiency." Crop Sci. 37, 481-491.

[17] "Investment Opportunity Profile For Cotton Production and Ginning in Ethiopia," 2012.

[18] "http://www.sciencedirect.com/science/article/pii/S0960852406000794"

[19] "http://buzzle.com/articles/cotton seed-oil-dangeres.html."

[20] "http://authoritynutrition.com/are-vegetable-and-see-oils-bad"

[21] "http://bonappetit.com/trends/article/3-best-and--worst-oils-for-your-health."

[22] "Williams, 2005."

[23] ".Michelle & Warden Ki, 2005."

[24] "Walkelyn & Wan, 2006."

[25] Dinesh K. Agarwal Phundan Singh Mukta Chakrabarty A J Sheikh S G Gayal, "Cottonseed Oil Quality Utilization And Processing'," CICR TECHNICAL BULLETIN NO:

[26] Agarwal AK, Rajamanoharan K. "Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines." Progress in Energy and Combustion Science 2007; 33(3):233–71.

[27] Demirbas A. "Progress and recent trends in biodiesel fuels." Energy Conversion and Management 2009; 50(1):14–34.

[28] Prusty BAK, Chandra R, Azeez PA. "Biodiesel: freedom from dependence on fossil fuels;" 2008 [cited 12 March 2011];

[29] Jain S, Sharma MP. "Prospects of biodiesel from Jatropha in India:" a review. Renewable and Sustainable Energy Reviews 2010; 14(2):763–71.

[30] Mahanta P., Shrivastava A. “Technology development of bio-diesel as an energy alternative;” 2011 [cited 12 March 2011];

[31] .Koh MY, Ghazi TIM. “A review of biodiesel production from Jatropha curcas oil.” Renewable and Sustainable Energy Reviews 2011; 15(5):2240–51.

[32] Balat M, Balat H. “A critical review of bio-diesel as a vehicular fuel.” Energy Conversion and Management 2008; 49(10):2727–41.

[33] Balat M, Balat H. “Progress in biodiesel processing.” Applied Energy 2010; 87(6):1815–35.

[34] Tewari, K. S., Mehrrota, S. N., Vishnoi, N. K., “Text Book of Organic Chemistry,” Vikas Publishing House Pvt. Ltd., New Delhi, India, 1985, pp. 585- 609].

[35] Murugesan A, Umarani C, Chinnusamy TR, Krishnan M, Subramanian R, Neduzchezhain N. “Production and analysis of bio-diesel from non-edible oils a review.” Renewable and Sustainable Energy Reviews 2009; 13(4):825–34.

[36] Juan JC, Kartika DA, Wu TY, Hin TY. “Biodiesel production from jatropha oil by catalytic and non-catalytic approaches: an overview.” Bio-resource Technology 2011; 102(2):452–60.

[37] B. Freedman, E.H. Pryde, T.L. Mounts. “Variables affecting the yield of fatty esters from transesterified vegetable oils,” Journal of American Oil Chemists Society 1984; 61(10):pp.1638–1643.

[38] G. Anastopoulos, Y. Zannikou, S. Stournas, S. Kalligeros. “Transesterification of vegetable oils with ethanol and characterization of the key fuel properties of ethyl esters,” Energies 2009; 2:pp. 362-376.

[39] L.C.Meher, D.Sagar, S. Naik. “Technical aspects of biodiesel production by transesterification,” Renewable and Sustainable Energy Review 2006; 10: pp. 248–268.

[40] Y. Zhang, M.A. Dubé, D.D. McLean, M. Kates. “Biodiesel production from waste cooking oil: Process design and technological assessment,” Bio-resource Technology 2003; 89: pp. 1–16.

[41] P. Nakpong, S. Wootthikanokkhan. “Optimization of biodiesel production from jatropha oil via alkali-catalyzed methanolysis,” Journal of Sustainable Energy and Environment 2010; 1: pp. 105-109.

[42] B. Freedman, R.O. Butterfield, E.H. Pryde. "Transesterification kinetics of soybean oil," Journal of American Oil Chemists Society 1986; 63:pp. 1375-1380.

[43] G. El Diwani, N. K. Attia, S. I. Hawash, "Development and evaluation of biodiesel fuel and by products from jatropha oil," Chemical Engineering and Pilot Plant Department, National Research Center, Dokki, Egypt Spring 2009; pp.219-224.

[44] Dennis Y.C. Leung, Xuan Wu, M.K.H. Leung, "A review on biodiesel production using catalyzed transesterification," Department of Mechanical Engineering, The University of Hong Kong, applied energy, 2009.

[45] A.A. Refaat. "Different techniques for the production of biodiesel from waste vegetable oil." International Journal of Environmental Science and Technology 2010; 7(1): pp. 183-213.

[46] Y.C. Leung, W.Xuan. "A review on biodiesel production using catalyzed transesterification," Applied Energy 2010; 87:pp.1083–1095.

[47] G. Vicente, M.Martınez, and J. Araci, "Integrated biodiesel production: a comparison of different homogeneous catalysts systems," Bio-resource Technology, vol. 92, pp. 297–305, 2004.

[48] A. A. Refaat, N. K. Attia, H. A. Sibak, S. T. El Sheltawy, and G.I. ElDiwani, "Production optimization and quality assessment of biodiesel from waste vegetable oil," International Journal of Environmental Science and Technology, vol. 5, no. 1, pp. 75–82, 2008.

[49] B. Freedman, R. Butterfield, and E. Pryde, "Transesterification kinetics of soybean oil," Journal of the American Oil Chemists' Society, vol. 63, no. 10, pp. 1375–1380, 1986.

[50] B. Freedman, E. H. Pryde, and T. L. Mounts, "Variables affecting the yields of fatty esters from transesterified vegetable oils," Journal of the American Oil Chemists' Society, vol. 61, no. 10, pp. 1638–1643, 1984.

[51] J. M. Marchetti, V. U. Miguel, and A. F. Errazu, "Possible methods for biodiesel production," Renewable and Sustainable Energy Reviews, vol. 11, pp. 1300–1311, 2007.

[52] B. K. Highina, I. M. Bugaje, and B. Umar, "Biodiesel production from Jatropha caucus oil in a batch reactor using zinc oxide as catalyst," Journal of Petroleum Technology and Alternative Fuels, vol. 2, no. 9, pp. 146–149, 2011.

[53] E. Lotero, Y. Liu, D. E. Lopez, K. Suwannakarn, D. A. Bruce, and J. G. Goodwin, "Synthesis of biodiesel via acid catalysis," Industrial and Engineering Chemistry Research, vol. 44, no. 14, pp. 5353–5363, 2005.

[54] Bryan R.Moser', "Biodiesel Production Properties, and Feedstocks'," Pp.1852-1859, March 25, 2009.

[55] American Society for Testing and Materials, Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels, Designation D6751-02, ASTM International, West Conshohocken, PA (2002).

[56] '"Fuel Quality standard improvement," by Berhanu Assefa (Dr. Eng) Addis Ababa Institute of Technology.

[57] Wrtyuui, "Fhkk;'," Diesel and Gas Engine Power Division of ASME Paper Number 78-DGP-19, International Journal of Engineering and Advanced Technology (IJEAT), Vol.2,Issue 4,New York,2010.

[58] Engelmann HW, guenther DA, silvis TW. "Vegetable oil as a diesel fuel." diesel and gas engine power division of ASME Paper Number 78-DGP-19, New York.

[59] Q. Gr., "Development in Use of Vegetable Oils as A Fuel for Diesel Engine," ASAE Paper Number 801525. St. Joseph, MI: ASAE; Vol. 4; Issue 8, Pp. 10-20; 2011.

[60] B.D., "Vegetable Oil fuel." International Journal of Energy and Environmental Engineering, Vol. 2, Issue 5, Pp.320-355, J Am Oil Chem.Soc 1981; 58(4).

[61] Barsic NJ, Humke AL "Vegetable Oils: Diesel Fuel Supplements," Automotive Engineering; Vol. 3, No. 3, 89(4) 2009.

[62] Reddy, P.N, Raju, A.V. "Experimental investigation on Jatropha biodiesel and additive in diesel engine." Indian Journal of Science and technology, 2009, Pp. 25 – 31.

[63] Marek, N.; Evanoff, J. "The Use of Ethanol Blended Diesel Fuel in Unmodified, Compression Ignition Engines:" An Interim Case Study. Proceedings of the Air and Waste Management Association 94th Annual Conference and Exhibition, Orlando, FL, 2001.

[64] Silitonga AS, Masjuki HH, Mahlia, Ong HC, Chong WT, Boosroh MH. "An Overview property of biodiesel diesel blends from edible and non-edible feedstock." Renew Sustain Energy Rev.2013; 22: 346-360.

[65] Mofijur A,N M., Rasul A M.G., Hydea J., Azada A.K., Mamatb R.,Bhuiya mmk. "Role of biofuel and their binary (diesel–biodiesel) and ternary (ethanol–biodiesel–diesel) blends on internal combustion engines emission reduction." Renewable and Sustainable Energy Reviews. 2016; 53:265-278.

[66] Shahir N S.A., Masjuki NN H.H., M.A. Kalam, Imran A., Ashraful Centre A.M.Performance and emission assessment of diesel–biodiesel–ethanol/ bioethanol blend as a fuel in diesel engines: A review. Renewable and Sustainable Energy Reviews, 2015; 48:62-78.

[67] Imtenan S., Masjuki H.H., Varman M., Rizwanul Fattah I.M., Sajjad H. Arbab M.I. "Effect of n-butanol and diethyl ether as oxygenated additives on combustion–emission-performance characteristics of a multiple cylinder diesel engine fuelled with diesel–jatropha biodiesel blend." Energy Conversion and Management. 2015; 94:84–94.

[68] Nord, A.J., J.T. Hwang, W.F. Northrop, 2015. "Emissions from a Diesel Engine Operating in a Dual-Fuel Mode Using Port-Fuel Injection of Heated Hydrous Ethanol", Proceedings of the ASME 2015 Internal Combustion Engine Division Fall Technical Conference ICEF2015 November 8-11, 2015, Houston, TX, USA, ICEF2015-1067, doi:10.1115/ICEF2015-1067

[69] Tanzer Eryilma, Murat Kadir Yesilyurt, Hasan Yumak, Mevlut Arslan', "Determination of the Fuel Properties of Cotton Seed Oil Methyl Ester and its Blends with Diesel Fuel." International Journal of Automotive, Engineering and Technologies, Vol. 3, No 2 Pp. 79-90, 2014.

[70] A.P. Sathiyagnanam, Member, Iaeng & C.G. Saravanan',, "Experimental Studies on the Combustion Characteristics and Performance of a Direct Injection Engine Fueled with Biodiesel/Diesel Blends with SCR'," In Proceedings of The World Congress on Engineering, London, U.K., VOL.3, JULY 6-8,2011.

[71] A. Siva Kumar, D. Maheswar, K. Vijaya Kumar Reddy', "Comparison of Diesel Engine Performance and Emissions from Neat and Transesterified Cotton Seed Oil'," Jordan Journal of Mechanical and Industrial Engineering, Vol.3, No.3 Pp.190-197, September 2009.

[72] “Section5 petroleum products lubricants and fossil fuels,” in ANNUAL BOOK OF ASTM STANDARDS, vol.05.02, ASTM international petroleum products and lubricants (ii): D2597-D4927, 2002.

[73] “ANNUAL BOOK OF ASTM STANDARDS,” in test methods for flash point by pensky martens closed cap tester, petroleum products and lubricants D0010-2596, 2002.

[74] EPA 1010A - TEST METHODS FOR FLASH POINT BY PENSKY-MARTENS CLOSED CUP TESTER

[75] Mitchell, K., J. Chandler, 1998. “The use of flow improved diesel fuel at extremely low temperatures”, SAE Technical Paper 982576, doi: 10.4271/982576

[76] “ASTM Standard Test Method For Kinematic Viscosity of Transparent and Opaque Liquids,” Designation: 71/1/97 D445-06

[77] J. Van Gerpen, B. Shanks, and R. Pruszko, “Biodiesel Analytical Methods,” National Renewable Energy Laboratory, Office of Energy Efficiency and Renewable Energy, By Midwest Research Institute, Battele, August 2002- January 2004.

APPENDIX

Cost analysis

s.no	material	unit	quantity	Unit price	Total price
1	Cotton seed	kg	50	12	600
2	Analytical grade methanol	liter	2.5	400	900
3	Catalyst KOH	kg	0. 5gm	700	350
4	Distilled water	liter	20	15	300
5	Tween80	liter	0.5	900	450
6	Characterization of biodiesel				7992
7	Jerican (plastic)	pcs	2	40	80
8	Diesel fuel	liter	20	18	360
9	Aluminum foil				100
10	soap	liter	1	35	35
11	rag	pcs	1	35	35
12	Transport cost				2500
12	others				10,000
total					23,702

Fuel characterization result from Ethiopian Petroleum Supply Enterprise (Quality Control Laboratory)

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የኢትዮጵያ ነዳጅ አቅራቢ ድርጅት
ETHIOPIAN PETROLEUM SUPPLY ENTERPRISE

Ref. No. 303/6·1·3·4·4/2017
26 ሐምሌ 2009

ለአዳማ ሳይንስና ቴክኖሎጂ ኒቨርስቲ
አዳማ

በቀን 27/10/2009 ዓ.ም በቁጥር MSVE/0050/3/2009 በተፃፈ ደብዳቤ ተማሪ ዝናቡ አጥናፉ በምርምር ያመረቱትን ባዮዲዝል ናሙና የላብራቶሪ የጥራት ፍተሻ እንድንሰራላቸው በጠየቃችሁት መሰረት የፍተሻው ውጤት እንደሚከተለው ቀርቧል፡፡

SN.	Property	Test Method AS TM	EPSE diesel Limits	ASTM D6751* limit for B100	Test Result			
					Cotton seed	5% ethanol B 20 75 % ADO	10% ethanol B 20 750% ADO	15% ethanol B 20 65 % ADO
1.	Density @ 15°C,g/ml	D 4052	Report	-	0.8885	0.8577	0.8563	0.8548
2.	Density @ 20°C,g/ml	D 4052	Report	-	0.8850	0.8542	0.8528	0.8513
3.	Flash Point (PMCC), °C	D 93	Min. 60	Min. 93	>116			
4.	Cloud point, °C	D 2500	Max. +5	Report	+7	-3	-3	-3
5.	Kinematic viscosity at 40 °C, mm^2/sec	D 445	1.9- 6.0	1.9 – 6.0	5.50	3.56	3.44	3.37
6.	Total acidity, mg KOH/g	D 974	-	Max.0.5	0.3	0.04	0.04	0.05

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

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

Liability

Ethiopian Petroleum 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 samples 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.

Best regards

Wolelsiw Taka
A/petroleum Quality Assurance
Service Head

1959 የኢትዮጵያ ነዳጅ አቅራቢ ድርጅት Ethiopian Petroleum Supply Enterprise 1966

ጥራቱን የጠበቀ የነዳጅ ምርት በማቅረብ የአገራችንን ልማት ለማፋጠን በሚደረገው ርብርብ ውስጥ የድርሻችንን እንወጣለን!