

TITLE AND COVER INFORMATION



ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS
ENGINEERING
DEPARTMENT OF THERMAL & AEROSPACE
ENGINEERING

Research Project Final Report Title of the Research Project:

EXPERIMENTAL INVESTIGATION ON CI ENGINE USED
FOR WATER PUMP SET WITH A BLEND OF NON-EDIBLE
VEGETABLE OIL AND ADDITIVE AS A STRAIGHT FUEL

By:-

SURESH GULUWADI (Ph.D)

August, 2020, Adama

Adama Science and Technology University

Terminal research reports submission format Office of research affair

[Address-Telephone-0221100053-E-mail-raff@astu.edu.et](mailto:raff@astu.edu.et) P.O.Box-1888

ABSTRACT

Gradual depletion of world petroleum reserves, and their impact on environmental pollution has motivated the scientific community to wards suitable alternative fuels for internal combustion engines. In the present work experimental investigations were carried out on the diesel engine operated on blends of non-edible oil. Blended fuel samples prepared by blending cotton seed oil (CO), jatropha oil and castor seed oil with gasoline and kerosene in steps of 3% of base oil. Out of these blended fuel samples, one sample of CO blended with gasoline and another sample CO blended with kerosene selected for further performance and smoke test. CI engine fueled with diesel operated for 10 hours and simultaneously performance and smoke emission tests were conducted. The procedure repeated with selected samples of cotton seed oil blended (COB) fuel. After each fuel operation engine piston, cylinder head, and valve and valve seating were orally observed for soot deposition. It was found that the soot deposition on piston, cylinder head and valve for both blended vegetable oil operation found to be minimal and comparatively higher than diesel fuel operation. BTE of both blended fuel with gasoline and kerosene is less compared to standard diesel (COB with gasoline by 4.68% and COB with kerosene by 5%). BSFC of both blended fuels is more compared to that of diesel. BTE of engine fueled with CO blended with gasoline was slightly superior (by 0.32 % at 80% load) compared to CO blended with kerosene. Whereas BSFC for both blended fuels are almost same at 80% load but more than diesel (by 5.8% at 100% load). The reasons could be that the blended vegetable oil being common the properties of kerosene and petrol had the bearing on the performance. The smoke emission is higher for both blended fuels compared to diesel could be due to incomplete combustion.

Keywords: Non-edible oil, Kerosene, Petrol, Emissions, Blended fuels.

ACKNOWLEDGEMENT

I owe an inestimable debt of gratitude to Dean, Associate dean (academics) and Associate dean(research) school of Mechanical, Chemical and Materials engineering, ASTU, Adama for their constant motivation in carrying out the research project. I also thank the program chair, thermal and aerospace engineering program, school of Mechanical Chemical and Materials engineering, ASTU, Adama for his constant support which led to successful completion of project.

I am thankful to HOD and technical staff of materials engineering department school of Mechanical Chemical and Materials engineering, ASTU, Adama for providing the testing facility.

I am also grateful to President and Vice president (Academics), ASTU, Adama, for their encouragement and continuous support for completion of the Project.

I would also like to thank every person who was directly or indirectly involved in carrying out this funded Project.

CERTIFICATE

This is to certify that the Research project “**Experimental Investigation on CI Engine used for Water Pump Set with a Blend of Non-Edible Vegetable Oil and Additive as a Straight Fuel**” is the original work. The work reported in this Project Completion Report has not been submitted in part or full to any other institutions and we declare that it is not the repetition of work carried out by others.

NAME OF THE INVESTIGATOR (S)	SIGNATURE	DATE
1. Dr SURESH GULUWADI	_____	_____
2. Mr. SAMUEL G/MARIAM	_____	_____
3. Mr .MEBRATU YISHAK	_____	_____
4. Mr DERESSE FIREW	_____	_____
5. Er PRAKASH C. H	_____	_____

TABLE OF CONTENT

TITLE AND COVER INFORMATION	i
ABSTRACT.....	iii
ACKNOWLEDGEMENT	iv
CERTIFICATE.....	v
TABLE OF CONTENT	vi
LIST OF FIGURES	ix
LIST OF TABLES.....	x
NOMENCLATURE	xi
CHAPTER 1	1
INTRODUCTION	1
1.1 COTTON SEED OIL (GOSSYPIUM HIRSUTUM).....	5
1.1.1 AVAILABILITY OF COTTON SEED AND OIL	5
1.1.2 PHYSICOCHEMICAL PROPERTIES OF COTTON SEED OIL	6
1.2 JATROPHA CURCAS SEED OIL	7
1.2.1 AVAILABILITY OF JATROPHA SEED AND OIL	8
1.2.2 CHEMICAL PROPERTIES OF JATROPHA SEED OIL.....	8
1.3 CASTOR (RICINUS COMMUNIS L) SEED OIL.....	9
1.3.1 AVAILABILITY OF CASTER SEED OIL.....	10
1.3.2 PHYSICOCHEMICAL PROPERTIES OF CASTER SEED OIL.....	10
1.4 SELECTION OF SEED AS AN ALTERNATIVE FUELS FOR CI ENGINE ON SINGLE FUEL MODE ENGINE OPERATION	11
1.5 STATEMENT OF THE PROBLEM.....	12
1.6 GENERAL OBJECTIVE.....	12
1.6.1 SPECIFIC OBJECTIVE	12
1.7 LIMITATION OF THE STUDY.....	13
1.8 SIGNIFICANCE OF THE WORK.....	13
1.9 JUSTIFICATION OF THE WORK	13
1.10 PRESENT WORK.....	14
CHAPTER 2	15
LITERATURE SURVEY	15
2.1 JATROPHA SEED OIL AND ITS BIODIESEL:.....	15

2.2 COTTON SEED OIL AND ITS BIODIESEL:	18
2.3 CASTOR SEED OIL AND ITS BIODIESEL:.....	21
2.4 LITERATURE SURVEY ON BIODIESEL AND KEROSENE BLENDED FUELS FOR DIESEL ENGINE APPLICATIONS:	22
2.5 KEROSENE AND PETROL BLENDED DIESEL FUELS FOR ENGINE OPERATION:.....	24
2.6 GENERAL VEGETABLE OIL AND BIODIESEL FUELED ENGINES	25
2.7 USE OF KEROSENE OR GASOLINE AS ADDITIVE FOR STRAIGHT VEGETABLE OILS:	26
2.7 SUMMARY OF LITERATURE REVIEW.....	27
CHAPTER 3	28
MATERIALS AND METHOD	28
3.1 METHODOLOGY	28
3.1 FUELS USED IN PRESENT WORK	29
3.2 PROPOSED FUEL PRODUCTION	34
3.3 EXPERIMENTAL SET UP	34
3.4 LOAD AND SPEED MEASUREMENTS	36
3.5 AIR FLOW MEASUREMENT	37
3.6 FUEL SUPPLY AND MEASUREMENT.....	37
3.7 TEMPERATURE MEASUREMENT	37
3.8 MEASUREMENT OF SMOKE	37
3.9 EXPERIMENTS CONDUCTED	38
CHAPTER 4	40
RESULT AND DISCUSSIONS	40
4.1 PERFORMANCE AND SMOKE TESTS DATA TABLE.....	40
4.2 EFFECT OF COTTON SEED OIL BLEND (COB).....	42
4.2.1 BRAKE THERMAL EFFICIENCY.....	42
4.2.2 SMOKE OPACITY	43
4.2.3 SPECIFIC FUEL CONSUMPTION:	44
4.2.4 SOOT DEPOSITION.....	45
4.3 OVERALL RESULT ANALYSIS.....	48
CHAPTER 5	49
CONCLUSIONS.....	49
5.1 BLENDING COTTON SEED, JATROPHA AND CASTOR SEED OILS	49

5.2 EXPERIMENTS WITH COTTON SEED OIL BLENDS WITH GASOLINE AND KEROSENE AT ENGINE MANUFACTURER SPECIFIED INJECTION TIMING AND PRESSURE.....	50
5.3 OVERALL CONCLUSIONS	50
5.4 SUGGESTIONS FOR FUTURE WORK.....	51
REFERENCES	52
APPENDICES	58
APPENDIX 1	58
APPENDIX 2.....	58
APPENDIX 3.....	59
CERTIFICATE.....	60

LIST OF FIGURES

Figure No	Title	Page No
1.1	Typical Molecular Structures of Diesel and Vegetable Oil	3
1.2	Cotton Seeds	5
1.3	Jathropha Seeds	7
1.4	Castor Seeds	9
3.1	Block Diagram of material Procurement and Processing	29
3.2	Castor, Cotton, and Jatropa seed oil respectively	30
3.3	Cotton, Castor, and Jatropa seed oil with Gasoline	30
3.4	Castor Oil Blended with Kerosene and Gasoline	30
3.5	Redwood Viscometer	31
3.6	Cleveland Open Cup Apparatus	31
3.7	Block Diagram of Experimental Setup	35
3.8	Single Cylinder Four Stroke DI Compression Ignition Engine Test Rig	36
3.9	Fuel Spray from Injector Nozzle Orifice	36
3.10	Injector Containing 3 Holes	36
3.11	Hartridge Smoke meter	38
4.1	Effect of COB on Brake Thermal Efficiency	43
4.2	Effect of COB on Smoke Opacity	44
4.3	Effect of COB on Specific Fuel Consumption	45
4.4	Injector Tips of Diesel fueled Engine and Blended Cotton Seed fueled Oil	46
4.5	Piston Top Surface and Ring Sticking with Diesel Fueled Engine and Blended Cotton Seed Oil Fueled Engine	46
4.6	Carbon Deposits on Cylinder Head with Diesel Fueled Engine Operation	47
4.7	Carbon Deposits on Cylinder Head with Blended Cotton Seed Oil Fueled Engine	47

LIST OF TABLES

Table No.	Title	Page No
1.1	Properties of some of the non-edible vegetable oils	3
1.2	Comparison of Physico-Chemical Properties of Cottonseed Oil and Diesel	7
1.3	Chemical Properties of Jathropha seed oil, compared with rape seed oil and European Standard Norms 14214	9
1.4	Physicochemical Properties of Castor Seed Oil	11
3.1	Castor Seed Oil Blended with Gasoline	31
3.2	Cotton Seed Oil Blended with Gasoline	32
3.3	Jathropha Seed Oil Blended with Gasoline	32
3.4	Castor Seed Oil Blended with Kerosene	32
3.5	Cotton Seed Oil Blended with Kerosene	33
3.6	Jathropha Seed Oil Blended with Kerosene	33
3.7	Test matrix for experimentation	39
4.1	Test Reading for Diesel Fuel	40
4.2	Test Reading for Cotton seed Oil blended with Gasoline	41
4.3	Test Readings for Cotton seed Oil blended with Kerosene	42

NOMENCLATURE

$^{\circ}\text{C}$	Degree Centigrade
%	Percent
A	Instantaneous area (m^2)
A/F	Air to Fuel
BDC	Bottom Dead Centre
bTDC	Before Top Dead Center
BSFC	Brake Specific Fuel Consumption.
BTE	Brake Thermal efficiency
CC	Cubic centimeter
CI	Compression Ignition
C_p	Specific heat at constant pressure
CA	Crank angle
COB	Cotton Seed Oil Blends
CR	Compression ratio
CO	Cotton seed oil
Cst	Centi stoke
D	Bore or Diameter
DEE	Diethyl Ether
DI	Direct Injection
FFA	Free Fatty Acid
Fig.	Figure
g	Gram
hr	Hour
HSD	High Speed Diesel
HSU	Hartridge Smoke Unit
IC	Internal Combustion
IOP	Injector opening pressure
IVD	Inlet Valve Diameter
K	Kelvin
Kg	Kilogram
kJ	Kilo Joules

Kpa	Kilo pascal
mm	Mille meter
MMT	Million Metric Tons
Ms	Mille seconds
N	Speed
n	No. of Cycles
R	Specific Gas Constant
r	Ratio of specific heats
SAE	Society of Automotive Engineers
SFC	Specific Fuel Consumption
SI	Spark Ignition
SVO	Straight Vegetable Oil
t	Time (s)
T	Cylinder gas temperature (K)
TDC	Top dead center
V	Instantaneous volume of the cylinder (m ³)
v/v	Volume basis
WVO	Waste Vegetable Oil

CHAPTER 1

INTRODUCTION

Gradual depletion of world petroleum reserves, and impact of environmental pollution have motivated the scientific community all over the world to look for suitable alternative fuels. Particularly diesel engines are the main prime movers for public and logistic transportation vehicles, stationary power generation units and agricultural applications in large proportions. Ethiopia imports 100% of its total crude oil requirement. This results in renewed focus on vegetable/plant oils. Straight vegetable oil (SVO) is an alternative fuel for petroleum diesel. It can be used as a fuel without engine modification and it also reduces the environmental impact. Several researchers have made systematic efforts to use plant oils and their esters as fuel in diesel engines. The use of non-edible vegetable oils as compared to edible oils is very significant in developing countries because of the tremendous demand for edible oils as food and hence they are far too expensive to be used as fuel at present. The usage SVO as fuel requires continuous heating for which engine requires inline heaters. The heating of SVO is up to a temperature of about 160°C with inline heaters is difficult to achieve. The difficulty in using SVO as fuel will be sticky in nature and it deposits at piston head, valve seating and at the cylinder head which needs to be cleaned periodically.

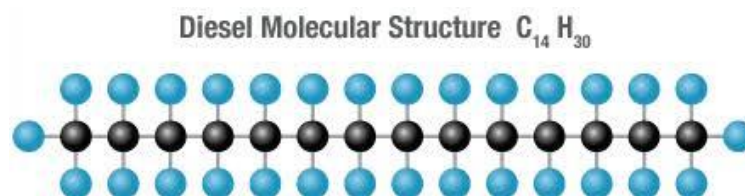
The increasing price factor coupled with increased awareness about environmental degradation has prompted governments and scientific community around the world over to look for suitable alternative fuels. During the last decade the use of alternative fuels for diesel engines has received renewed attention. It is important to explore the feasibility of alternative fuels and their substitution of diesel, which can be produced within the country on a massive scale for commercial utilization. As far as Ethiopia country is concerned, the need to search for alternative fuels is more urgent as Ethiopia is heavily dependent upon the import of petroleum products to meet its demands for automotive, agricultural and power sectors. In this context, a few fuels that are gaining prominence are as follows:

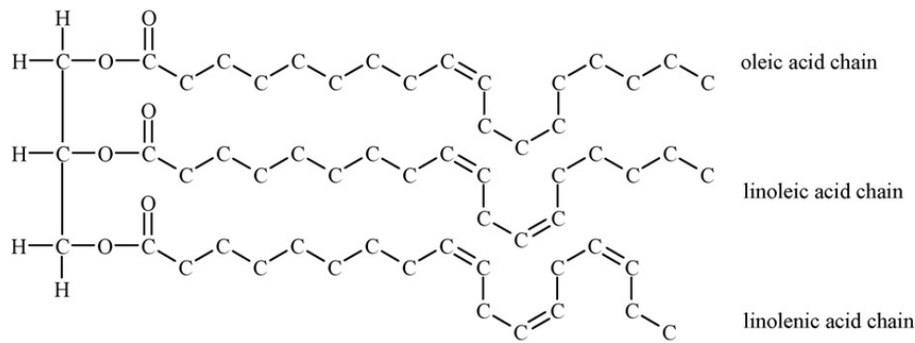
1. Alcohol fuels (Methanol and Ethanol)
2. Compressed Natural gas (CNG)
3. Biogas
4. Producer gas
5. Liquefied Petroleum Gas (LPG)

6. Hydrogen, and
7. Biodiesels.

Research in this direction with vegetable oils has yielded encouraging results. Vegetable oils present a very promising alternative to diesel oil since they are renewable and have similar properties. Many researchers have studied the use of vegetable oils in diesel engines. Vegetable oils offer almost the same power output with slightly lower thermal efficiency when used in diesel engine. Reduction of engine emissions is a major research aspect in engine development with the increasing concern on environmental protection and the stringent exhaust gas regulation.

The alternative liquid fuels must be technically and environmentally acceptable and economically competitive. The prime liquid alternative fuels are alcohols and vegetable oils. Both alcohols and vegetable oils are derived from biomass i.e. from renewable fuel. Like diesel fuel, vegetable oils also have acceptable heating value and ignition quality. Vegetable oil is triglycerides, which are esters of long chain fatty acids and polyalcohol glycerol. Vegetable oils typically have large molecules, with carbon, hydrogen and oxygen being present. The typical molecular structures of diesel and vegetable oil are presented in Figure 1.1. Hence, vegetable oils and their methyl esters are alternative renewable fuels for compression ignition engines replacing fossil diesel. Inherent properties of vegetable oils make them suitable for use in diesel engines solely with an acceptable loss in efficiency. Vegetable oils have comparable energy density and cetane number to mineral diesel. Vegetable oils are considered as good alternatives to diesel as their properties are close to diesel. Thus, they offer the advantage of being able to be readily used in existing diesel engines without any modifications. They have a structure similar to diesel fuel, but differ in the type of linkage of the chains and have a higher molecular mass and viscosity. The presence of oxygen in vegetable oils raises the stoichiometric fuel air ratio. The carbon residue of vegetable oil is higher than diesel fuel.





Molecular Structure of Vegetable oil (example applies for rapeseed oil).

Figure 1.1 Typical molecular structures of diesel and vegetable oil

Table 1.1 compares some of the important properties of different non-edible vegetable oils, which are used either directly or in the form of its methyl esters as fuels in diesel engines. These properties will determine its performance as fuel.

Table 1.1 Properties of some of the non-edible vegetable oils*

Properties	Diesel	Jatropha oil	Karanja oil	Polanga oil	Rubber seed oil	Mahua oil	Neem oil
Viscosity 40 C (mm ² /s)	7.5	18.2	27.8	72.0	76.4	24.6	-
Flash point °C	50	174	205	221	198	232	-
Calorific value (Mj/kg)	42.25	38.2	34.0	39.3	37.5	36	34.5
Iodine value (g/100 g)	38.3	93	80.9	93.8	135.3	74.2	69.3

(* Source: Azam et al 2005[1], Gadge and Raheman 2005[2], Karmee S Chadha 2005[3], Ramdas et.al 2005[4]).

A number of vegetable oils have been tested all over the world to evaluate their performance in diesel engines. Some of them like Neem oil, Palm oil, Honge oil, Rape seed oil, Coconut oil, Cottonseed oil, Jatropha oil, Mahua and Rubber seed oil have been found to be viable. Studies have revealed that some of these oils can directly substitute diesel in electricity generating sets and irrigation pump sets with no modifications. Such oils when used without modifications are commonly known as ‘Straight Vegetable Oils’ (SVO). While using SVO as fuel in diesel engine it is essential to know the following physicochemical properties of these oils:

Saponification Value: It represents the number of milligrams of Potassium hydroxide or Sodium hydroxide required to saponify 1g of fat under the conditions specified. It is a measure of the average molecular weight of all the fatty acids present.

Iodine Value: The iodine value of a substance is a measure of the degree of chemical saturation in a chemical olefinic bond. Iodine values are used to determine the oxidative stability of a fuel in order to determine storage stability. Higher iodine value indicates more unsaturated bonds, which equate to less storage stability. Thus, iodine number refers to the amount of iodine required to convert unsaturated oil into saturated oil.

Acid Value: It is the number of mg of Potassium hydroxide required to neutralize 1g of a chemical substance. It is a measure of the amount of carboxylic acid groups in a chemical compound such as a fatty acid.

Calorific value: The calorific value of a fuel is a measure of the amount energy (calories) that the fuel contains per unit mass.

Density: The density of a fuel is a measure of its weight per volume. The density of the fuel is important because many diesel engine fuel injection pumps use the weight of the fuel for measurement and dispensing.

Viscosity: It is the measure of the thickness of a fluid. Viscosity is an important measure of a fuel because the atomization characteristics of the fuel are affected by it. Moreover, it is important for the flow of oil through pipelines, injector nozzles and orifices. Viscosity of fluids varies inversely with temperature.

Cetane Number: It is a measure of ignition quality of diesel fuels. The cetane number of a fuel is the percentage by volume of cetane in a mixture of cetane and α -methylnaphthalene ($C_{10}H_7CH_3$) that has the same performance in the standard test engine as that of the fuel. Higher cetane number has shorter ignition delay. The cetane number of diesels is 48.

Cloud Point: It is the temperature at which the fluid develops ice crystals and begins to clog small openings, such as fuel filters. This measure becomes important in cold climates.

Pour Point: It is the lowest temperature at which a fluid will flow. This property is relevant in cold places.

Flash point: Flash point of a fuel is defined as the temperature at which it will ignite when exposed to a flame or spark.

Refractive Index: It is the measure of reduction in speed of light inside the medium

Vegetable oil has higher viscosity and lower volatility and causes improper atomization of fuel during injection. This leads to smoky exhaust in a diesel engine. The other problems are clogging of nozzle orifice, poor atomization and vaporization and results in incomplete combustion. The higher viscosity of oil changes the spray pattern and droplet size. The longer engine trials have resulted in injector chocking, engine deposits, ring sticking, thickening of engine and lubricating oil which reduces engine life. The polyunsaturated nature of the vegetable oil causes long-term problems due to slow polymer gum formation causing ring sticking. Because of these problems,

1.1 COTTON SEED OIL (GOSSYPIUM HIRSUTUM)

Cottonseed contains hull and kernel. The hull produces fibre and linters. The kernel contains oil, protein, carbohydrate and other constituents such as vitamins, minerals, lecithin, sterols etc. Crude cottonseed oil is extracted from cottonseed kernel and its colour is of pale yellow. This section presents about availability data of Cottonseed and Cottonseed oil as well as its yield per kg of seeds. It also presents its physicochemical properties and composition of free fatty acid. Figure 1.3 shows cotton seeds.



Figure 1.2 Cotton Seeds

1.1.1 AVAILABILITY OF COTTON SEED AND OIL

Cotton was grown in 90 countries. Cotton cultivation cost is lower in Africa as compared to other countries. But, the share of African countries in the world market is only 12%. In this continent, cotton is typically a smallholder crop. The global production of cotton was 26.78 million tons in MY 2017/18, which increased by 2.27 per cent to 26.42 million

tonne in MY 2019/20. Around 30 million Square Km land mass endowed in Africa which is equivalent to combined land of USA, Japan and Brazil (Yang 2014) [1]. Africa is the fastest growing population of cotton seed with an average increase of 60% - 80% transport fuel in African country by 2030 (World Bank (2008)) [2]. Hence researchers are focused towards on the non-edible oil seeds, which is most abundant in African countries such as Ghana, Zambia, Liberia, Tanzania, Ethiopia, Nigeria, Senegal, Kenya and South Africa. (Oye-lade et al., 2017; Ogunkunle et al., 2017; Ogunkunle and Ahmed, 2019b) [3,4,5]

Ethiopia is one of the African countries that produce and export cotton. It has a long tradition of cotton cultivation with an estimated area of 2.6 million hectares suitable for this product. Of these 65% is found in 38 high potential cotton-producing areas and the remaining 0.9 million ha or 35% is in 75 medium potential districts. Of the total land under cotton cultivation, 33% is cultivated by small holders, 45% by private farms and 22% are state-owned farms. But Ethiopia shares only 5% of total cotton produced in Africa. This is because it recently cultivates only 3% of the total suitable land for cotton production. Ethiopia produces an average of 33,842.11 metric tonnes in the year 2000–2018. Ethiopia is also part of sub-Saharan African countries that produce and export cotton.

Cotton seed oil (CSO) is extracted from the seeds of cotton plant of various species, mainly *Gossypium hirsutum* and *Gossypium herbaceum*. Cotton seed has an oil-bearing kernel surrounded by a hard-outer hull; while processing, the oil is extracted from the kernel. Cotton seed oil is environmentally safe. It is a byproduct of cotton tree. At present, cotton seed oil has not found any major application and hence the natural production of seeds remains underutilized. As a compression ignition engine fuel, cotton seed oil has a high cetane number of 45, which is very close to diesel. The properties of cotton seed oil are very close to diesel. This makes it a suitable alternative fuel for diesel engines.

1.1.2 PHYSICOCHEMICAL PROPERTIES OF COTTON SEED OIL

Cottonseed oil is often used as the standard for measuring flavor and odor qualities of other oils. Cottonseed oil has a mild taste. It has a clear light golden colour, but like most oils, the degree of color depends on the amount of refining. Cottonseed oil's light, non-oil consistency and high smoke point make it most desirable for diesel engines. Analytical

values on different parameters for various cottonseed oil forms are given in Table 1.2 below:

Table 1.2: Comparison of physicochemical properties of Cotton oil and diesel

S. No.	Parameters	Cotton seed oil	Diesel
1	Saponification Value (mg KOG/g)	191-196	0
2	Iodine value (g/100 g)	100-117	38.30
3	Acid Value (Max.) mg KOH/g	0.05	0.06
4	Moisture (% max.)	-	24.66
5	Colour in ¼ inch cell (Y+5R)	-	102.5
6	Refractive Index (40°C)	-	1.472
7	Specific Gravity (30°C)	0.915-0.920	0.82 – 0.86
8	Cloud Point (°C)	-1	0
9	Pour Point (°C)	-3	-8

*NCPA-National Cotton Seed Product Association *CICR-Central Institute for Cotton Research.

1.2 JATROPHA CURCAS SEED OIL

Jatropha is a genus of flowering plants in the spurge family, Jatropha contains compounds that are highly toxic. Jatropha species have traditionally been used in basketmaking, tanning and dye production. In the 2000s, one species, Jatropha curcas, generated interest as an oil crop for biodiesel production when used as lamp oil and also medicinal importance. The oil from Jatropha curcas is mainly converted into biodiesel for use in diesel engines. The cake resulting from oil extraction, a protein-rich product, can be used for fish or animal feed (if detoxified). It is also a biomass feedstock to power electricity plants or to produce biogas, and a high-quality organic fertilizer. Fig 1.3 shows jathropha seeds collected from local area.



Figure 1.3 Jatropha seeds

1.2.1 AVAILABILITY OF JATROPHA SEED AND OIL

Jatropha have been propagated around 1,000,000 ha in the world. The majority of the Asian countries (85%) like India, China and remaining 12% in Africa and 2 % in Latin America [6]. This seed is growing with a lower latitude of 0-500 meters above the sea level (Heller, 1996) [7]. This can survive with little rain fall of 200 to 300 mm annually (FACT 2007, Achten 2008) [8]. The optimum temperature is between 20 to 28°C, if it exceeds the temperature can depress the yield of the seed (Gour 2006) [9]. This had a high intensity of light conditions and it is unsuited in growing in shade (Jongschaap, 2007) [10]. The oil content ranginf from 18.4 to 42.3 % (Heller, 1996) [6]. This can be compared with the other seed such as ground kernel (42%), soybean (14%), Sunflower oil (32%) with an oil content ranging from 50 to 55% (Jangschaap 2007). Globally Jatropha has been planted around 12.8 million ha in the year 2015, which includes Africa, Ghana Indonesia and Brazil etc.

Individual environmental factor effects the suitability of Jatropha production in Ethiopia. But as per the topological considerations most of the Ethiopian part is suitable for Jatropha production. Around 65.8% of the elevation and the 95% of the slops are suitable for Jatropha seed cultivations. The total area of 176,026 ha with altitude ranging between 900-1600 meters above sea level (Feto 2011) [11] are used for the pastoral and agro pastoral production systems for agricultural practice in Ethiopia. Around 85 companies are licensed to invest on Jatropha seed production in Ethiopia. When, it comes to small- and large-scale production of Jatropha seeds received a better attention in most of the African countries. In order to reduce the annual \$1 billion cost of importing petroleum the Ethiopian government several years ago began showing an inedible plant called Jatropha Curcas on plantations in Benishangul, Wolayta, Wollo and Tigrai and some eastern regions of Ethiopia to produce bio-diesel for domestic use. Regional forestry and agro forestry team leader Tsega ab Teka told VOA, “the plant was introduced in Tigrai and in 2006 more than 1.6 million seedlings were planted in 13 woredas and 80 percent of the seedlings have survived. Moreover, 10 million Jatropha Curcas seedlings are being planted in eight woredas of Tigrai in this Ethiopian summer.”

1.2.2 CHEMICAL PROPERTIES OF JATROPHA SEED OIL

Chemical analyses were completed on Jatropha curcas oil extracted from mechanical screw press and results were compared with properties of Raps oil and EN 14214 (Table

1.3). The density and kinematic viscosity of J.curcas was lower than Raps oil but higher than the European Standard. Gross calorific value and iodine value was comparable with Rape seed oil and EN 14214.

Table 1.3: Chemical properties of Jatropha seed oil compared with rape seed oil and European Standard Norms 14214

Property	J. Curcas oil	Rape seed oil	EN 14214
Density kg/m ³	914	920	860 -900
Kin viscosity mm ² /s (40°C)	31.2	35.8	3.5 – 5.0
Gross calorific value MJ/kg	39.66	39.6	>35
Iodine value g/100g	100	111	<120
Impurities, C% mass/ max	0.11	.19	<0.3
Water content mg/kg	822.8	609.4	<500
Acid value KOH/g	2.81	1.68	<0.50

***Source:** conference published paper of “Conference on International Agricultural Research for Development” Physical, mechanical and chemical properties of Jatropha curcas, seeds and kernels” by Karaj, Shkelqim, Huaitalla, Roxana Mendoza Müller, Joachim

1.3 CASTOR (RICINUS COMMUNIS L) SEED OIL

Castor oil is a vegetable oil pressed from castor beans. The name probably comes from its use as a replacement for castoreum. Castor oil is a colorless to very pale-yellow liquid with a distinct taste and odor. Its boiling point is 313 °C (595 °F) and its density is 961 kg/m³. It is a triglyceride in which approximately 90 percent of fatty acid chains ricinolates. Oleate and linoleates are the other significant components. Castor oil and its derivatives are used in the manufacturing of soaps, lubricants, hydraulic and brake fluids, paints dyes, coatings, inks, cold resistant plastics, waxes, polishes, nylon, pharmaceuticals and perfumes. Figure 1.4 shows castor seeds collected locally.



Figure 1.4 Castor Seeds

1.3.1 AVAILABILITY OF CASTER SEED OIL

Castor oil is a vegetable oil with a boiling point of 313°C and density of 961 kg/m³. The major ten countries to produce large production are India (1,74,4000 Tones), China (60,000 tones), Ethiopia (13,000 tones) followed by Thailand (12,000 tones), Brazil (11,923 tones), Paraguay (11,000 tones), south Africa (6,200 tones) and Pakistan (6,000 tones) respectively. In the year 2019-20 around 10.82 lakhs tones castor seed oil produced in the world. Castor oil was globally increased by volume in the market by 763 Kiloton in 2018. It may research about 943.5 Kilotons by 2024. Globally in the year 2019-2024 there is growth of around 3.5%. The castor oil seed produce 2,389 kg/ha in the last year 2019-20, with an increase of 36%.the castor seed growing with moderately high temperature, based on the season gives a maximum yield at low humidity condition. The duration of the crop is growing between 145 to 280 days based on breads and verity of seeds. The country with the largest volume of the castor oil seed output was India accounting for major contribution of global production. The second largest castor oil seed output recorded by Mozambique. The third position in this ranking was occupied by China with accountable production. The remaining producing countries in the decreasing order of production are Brazil, Ethiopia, Myanmar, Paraguay, Vietnam, South Africa and Angola respectively.

The potential of castor seeds in Ethiopia had major role for the oil production, because dry regions suitable for the growing of castor seeds especially in Asosa zone that is located in the west of the country near the border of Sudan. The suitability of the growing condition zone is between 1600 to 2600 m above sea level and the climate condition of dry and warm region with an average rain fall distribution of 550 to 700 mm. As the plant is very robust in nature and it can grow with 6 to 15 feet means 2 to 5 meters in one season with sunlight (Wijnands, etal) [12]. The interesting thing is Ethiopian production is over 100000 tons annually based on the world trade survey. Therefore, the oil seed production increased by 17% (10,930 tones) in the year 2018 compared to previous year (2017).

1.3.2 PHYSICOCHEMICAL PROPERTIES OF CASTER SEED OIL

The physicochemical characteristics of the castor oil were evaluated. The results showed that the castor seeds contain a relatively high percentage of total lipids content; 47.8 %, iodine value (1.061 g/100g), and saponification value (327.4 mg/g). The seed oil moisture

content, acid value, density and free fatty acid (% FFA) were 0.3 %, 14.42 mg/g, 880 g/cm³ and 7.21 %, respectively.

The chemical properties such as iodine value (IV), acid value (AV), free fatty acid (FFA) and saponification value (SV) were determined by titrimetric analysis. The moisture content was also determined. Whereas physical properties such as density (ρ), specific gravity (SG) and percentage yield of the oil extracted were determined. The following table 1.4 gives physicochemical properties of castor oil.

Table 1.4: Physicochemical Properties of Castor oil

Parameters	Value
Lipid content (%)	47.8
Moisture content (%)	0.3
Iodine value (1gm/100 gm)	1.061
Acid value (mg/g)	14.42
Free fatty acid (%)	7.21
Saponification value (mg/g)	327.4
Density (g/cm ³)	880

*Source: Fatty Acid Composition and Physicochemical Properties of Castor (*Ricinus Communis L*) Seed Obtained from Malete, Moro Local Government Area, Kwara State, Nigeria.

1.4 SELECTION OF SEED AS AN ALTERNATIVE FUELS FOR CI ENGINE ON SINGLE FUEL MODE ENGINE OPERATION

One of the criteria for selecting a particular fuel for CI (Compression ignition) engines is that it should be available everywhere and renewable. These selected seeds are locally available and can be used for production of oils easily using portable type of oil expeller and vegetable oil always has potential to be used as fuel for diesel engine by lowering its viscosity. This motivated to take up this project to use selected oils a fuel in diesel engine. Single fuel feeding to diesel engines is a common and popular approach. The single fuel engine is a conventional diesel engine in which much of the energy released, and hence power comes from the combustion of a fuel such as diesel/biodiesel/blended fuel. This engine can accept a wide range of liquid and gaseous fuels. The merits of this approach lie in the fact that an existing CI engine can be operated on blended vegetable oil with marginal modifications and without forgoing the option of straight diesel operation of the machine. The blended jatropha, cotton seed and castor seed oils with gasoline and kerosene were selected as alternative fuels for CI engine applications due to their availability and their non-edible nature. They can provide a sustainable and viable option for the use in diesel engine applications.

1.5 STATEMENT OF THE PROBLEM

The rapid depletion of fossil fuels and degradation of environment due to combustion of fossil fuels have caused resurgence of interest in finding alternative fuels. The evaluation of feasibility of using a variety of alternative fuel has been of utmost concern. Rapid progress in the direction of using non-edible vegetable oil or their derived biodiesel for compression ignition is undertaken in order to become independent of diesel. The blends of vegetable oils derived from Jatropha, cotton seed oils with kerosene and petrol are popular contenders for use as alternatives to diesel and this area needs rigorous research to ascertain feasibility of the myriad fuels available in nature. Hence present work evaluates such a combination of fuels towards partial elimination of diesel fuels. The present study deals with the optimal design of the following aspects of a non-edible oil with additives as CI engine fuels.

Review of literature reveals that the blended vegetable oils derived from Cotton, Jatropha and Castor seeds are good contenders for use as alternative fuel to diesel and also very limited work has been done to assess their suitability to use them as an alternative fuel in CI engine. Hence, this work was carried out with following objectives.

- (1) To extract oil from Cotton, Jatropha and Castor seeds and blend them with gasoline and kerosene.
- (2) To characterize these blended vegetable oils for viscosity, flash point and fire point.
- (3) To select best sample of blended vegetable oil with gasoline as well with kerosene based on its viscosity.
- (4) To develop experimental setup and to carryout investigation using single cylinder diesel engine operated with test fuels (blended vegetable oils) with conventional fuel injection system.

1.6 GENERAL OBJECTIVE

General objective of this research proposal is to develop easily producible alternative fuel in the form of blends of non-edible oil with additives of kerosene and gasoline. The alternative fuel can be used directly in a diesel engine without further processing or heating. The fuel can be effectively used by the farmers to operate irrigation pump-sets with minimum cost.

1.6.1 SPECIFIC OBJECTIVE

- To prepare the samples of fuel mixture (cotton seed, jatropha and castor seed vegetable oil blended with kerosene and gasoline) in steps of 3%.

- To determine viscosity, flash and fire point of all the samples of fuel.
- To identify one best sample of vegetable oil blended with gasoline and another sample of vegetable oil blended with kerosene based on the properties which near to diesel.
- To test the best samples by fueling in to the diesel engine in single fuel mode.
- To compare the components of engine for deposition carbon soot and wax.
- To determine brake thermal efficiency and fuel consumption rate of best identified two samples.

1.7 LIMITATION OF THE STUDY

Scope of the study is limited to experimental investigation of blended vegetable oils of cotton, jatropha and castor seed oils as a substitute for diesel in compression ignition engines in single fuel mode of operation. As per the proposal the study is limited to experimental investigation on single cylinder CI engine with manufacturer supplied injection timing and injection opening pressure. The experimentation is limited to laboratory test data extraction, analyzing and drawing conclusion.

1.8 SIGNIFICANCE OF THE WORK

The study plays a role in finding a way to produce alternate renewable fuel for CI engine in a crude way in rural places of Ethiopia. With further additional investigation on local available seeds could be converted into renewable source of fuel for CI engine. This leads to saving of country's foreign exchange. After successful completion of investigation on different types of CI engines govt or private entrepreneurs could establish indigenous cottage industries on production of fuel replacing diesel in rural areas of Ethiopia.

1.9 JUSTIFICATION OF THE WORK

The depletion of fossil fuels with a simultaneous exponential growth in energy demands has made it necessary to take a conservative step in the utilization of the fossil fuels. Ethiopia annual requirement of oil is 114 million tons. Even a slight replacement of petroleum fuel by blends of non-edible oils with additives like kerosene, petrol can help Ethiopia to save a substantial amount in terms of foreign exchange. High polluting nature of petroleum fuels justifies the use of blended vegetable oil as an alternative to the fossil

fuels. Abundant availability of above-mentioned energy content seeds in Ethiopia is presently underutilized. The present work aimed to utilization of these seeds to its full potential. Thus, the project is justified in the present context as it aims at minimizing to certain extent dependence on fossil fuels through efficient utilization of above fuel combinations, which is renewable in nature.

From the literature survey it was observed that vegetable oils can be used as fuel in diesel engine by bringing its viscosity to very nearly equal that of diesel. The viscosity of vegetable oil can be reduced by heating them to a sufficient temperature (around 160 °C). This has led to the development of inline-heaters in diesel engines. All currently available inline-heaters however, can only heat the oil up to about 80 °C which is ineffectual in bringing the viscosity of pure oil to the required range. If at all the heater capacity increased majority of energy developed would be consumed for heating oil. Many researchers used heated and processed additives-based vegetable oil as fuel for diesel engine. But none used vegetable oil as fuel without heating or processing. Hence, the present work is focused on use of non-edible vegetable oil as fuel without being heating and processing.

1.10 PRESENT WORK

Present work is focused to use of non-edible oil as fuel without being heating and processing. In this proposal would like to find the viscosity, fire and flash point temperatures for the three most popular non-edible oils available in Ethiopia such as Jatropha oil, Castor oil and Cotton seed oil mixed with Kerosene and gasoline in steps of 3% as additives up to a 20 to 24 % as per literature survey. Further by studying the properties of these fuel mixture the two best fuel mixture one with gasoline another with kerosene will be selected as fuel in diesel engine. The engine will be made to run for about 10 hours with diesel and as well as with chosen mixture (non-edible oil with additives). The deposition on the piston head, valve seating and cylinder head will be observed and compared the same with diesel fueled engine parts. Further performance test will be conducted with chosen mixture as fuel to determine BTE and SFC.

CHAPTER 2

LITERATURE SURVEY

The internal combustion engine designed, built, and demonstrated by Rudolf Diesel at the 1900 Paris World's Fair ran on peanut oil. This was the product of his dream-an efficient internal combustion engine, powered by crude oil or even vegetable oil. Vegetable oils have considerable potential to be considered as appropriate alternate fuel as they possess fuel properties similar to that of diesel. Moreover, review of literature revealed that with the use of vegetable oils, as fuel in diesel engines is beneficial because, these are non-toxic, biodegradable, eco-friendly and renewable in nature and the use of vegetable oils in diesel engine reduces emissions. Ethiopia has rich and abundant forest resources with wide range of plants and oil seeds. There are more than 200 different species of trees available in Ethiopia. The oils can be obtained from many oil seeds. Based on the application or use of vegetable oils, the vegetable oils are classified in to two types, namely, edible and non-edible oils. Economics of the biodiesel production process can be improved, if non-edible oils are used. Use of edible oils in diesel engines is not encouraged as it is in great demand for human consumption [15, 16, 17, 18]. A detailed literature survey was conducted on the biodiesel oils as well as different methods of using them in normal diesel engine. Literature pertaining to the development, performance engines using blended oils was studied to ascertain their suitability as the injected fuel.

2.1 JATROPHA SEED OIL AND ITS BIODIESEL:

Sahoo et al. (2009), [13]. investigated the performance and emission characteristics of a tractor engine fueled with biodiesels derived from Jatropha, Karanja and Polanga oils. Experimental results were generated under full/part throttle position for different engine speeds (1200, 1800 and 2200 rev/min). Maximum increase in power was observed for 50% jatropha biodiesel and diesel blend at rated speed. For all the biodiesel blends, brake specific fuel consumptions increased with blend ratio and decreased with speed. Reduction in smoke for all the biodiesel and their blends when compared with diesel and speed was reported during full throttle performance test.

Haldar et al. (2009), [14]. conducted performance and emission tests in a variable compression ignition engine operated on degummed non-edible oils of Jatropha, Karanja, Putranjiva and their blends at various injection timings. Smoke and particulates

of all the three oils used were lower than diesel. 20% blends of Jatropha and Karanja oils resulted into improved performance compared to diesel.

Berchmans et al, (2008) [15]. experimented a two-step process for the production of biodiesel from Crude Jatropha Curcas seed Oil having high free fatty acids. The authors found that the free fatty acid in jatropha curcas oil was reduced to less than 1% after carrying out the transesterification process at 50oC and 65oC using H₂SO₄ and NaOH as catalysts respectively. The final yield for biodiesel achieved was 90%.

Seema et al, (2017) [16]. discussed transesterification of Jatropha oil and discussed physico-chemical properties, fatty acid composition of JC in this review along with the comparison of homogenous and heterogeneous techniques. They highlighted mainly high oil yield, lipid enhancement using various technical processes.

Silitongaab et al, (2011) [17]. discussed the potential of Jatropha oil in Indonesia and their study mainly highlights with the prospect of biodiesel produced from J. curcas. Summary and overview of energy resources and total consumption of Jatropha in the country has been reported. In addition, they discuss the potential of biodiesel as a powerful renewable energy resource. They reported that production of biodiesel from Jatropha curcas offers many social, economic and environmental benefits for the country and can play a great role to solve the problem of energy crisis in Indonesia

Deng et al, (2011) [18]. have used hydrotalcite-derived particles (Mg/Al molar ratio of 3/1) of nanosize for biodiesel production and is used as a catalyst. Experiments were conducted with the solid basic catalyst in an ultrasonic reactor under different conditions. They found optimized conditions like biodiesel yield of 95.2%. They reported that the catalyst can be reused for 8 times.

Abdul Khalil et al, (2013) [19]. reviewed Jatropha biomass as renewable materials for bio composites and its applications. They have reported the main advantages of Jatropha biomass. They discussed the distribution of Jatropha around the globe, chemical composition of various parts and extracts of Jatropha and their mechanical and physical properties. They have also discussed Jatropha biomass for various technical and bio composite applications. They highlighted Jatropha latex and it can be reduced to nanoparticle size. The chemical and physical properties of Jatropha contribute to its applications in food and non-food Products.

Augustus et al, (2002) [20]. studied the composition of Jatropha oil and measured the properties of Jatropha curcas biodiesel. It was found that the gross heat value for raw seed

was 20.85 MJ/kg, and that of oil was 37.83 MJ/kg. The hydrocarbon was 40.63 MJ/kg. The oil fraction contains saturated fatty acids, palmitic acid (14.1%), stearic acid (6.7%), unsaturated fatty acids, oleic acid (47.9%), and linoleic acid (31.6%).

Karthikeyan et al, [21] The aim of the study is to use fish oil methyl ester (FME) and Jatropha oil methyl ester (JME) as a substitute for diesel in compression ignition engine. Experiments were conducted when the engine was fuelled with Diesel, Fish oil methyl ester and Jatropha oil methyl ester. The experiment covered a range of loads. An AVL smoke meter was used to measure the smoke density in HSU (Hatridge Smoke Unit). The exhaust emissions were measured using exhaust gas analyzer. High volume sampler was employed to measure the particulate matter in exhaust. The performance of the engine was evaluated in terms of brake specific fuel consumption, brake thermal efficiency. The combustion characteristics of the engine were studied in terms of cylinder pressure with respect to crank angle. The emissions of the engine were studied in terms of concentration of CO, NO_x, particulate matter and smoke density. The results obtained for Fish oil methyl ester, Jatropha oil methyl ester, were compared with the results of diesel. Bio-diesel, which can be used as an alternate diesel fuel, is made from vegetable oil and animal fats. It is renewable, non-toxic and possesses low emission profiles.

Fattah et al, (2014) [22], studied oxidative degradation due to autoxidation in the presence of oxygen. They showed reduced degradation when antioxidant was added. In their study they have used Coconut (*Cocos nucifera*) and Jatropha (*Jatropha curcas*). They studied the effect of an antioxidant addition on the performance and emission characteristics of a four-cylinder diesel engine fueled with B20 of two biodiesels (CB20 and JB20). Performance results indicate that JB20 and CB20 showed, respectively, 0.95% and 2.97% lower mean brake power (BP) and 5.02% and 4.76% higher mean brake-specific fuel consumption (BSFC) compared to diesel. They found increased brake power and reduced BSFC with addition of antioxidants. Emission results show that untreated JB20 and CB20 increased nitrogen monoxide (NO) emission by 5.52% and 8.02%. But reduced carbon monoxide (CO) and hydrocarbon (HC) emissions have been reported. Antioxidant-treated blends reduced NO emission by 2.6–5.0%, but increased CO emission by 4.9–20.8% and HC emission by 23.2–40.2% compared to B20 depending on feedstock. Thus, antioxidant-treated JB20 and CB20 blends can be used in diesel engines without any modification.

Chauhan et al, (2011) [23], investigated the performance, emission and combustion characteristics of dual fuel diesel engine fueled with biodiesel derived Jatropha oil and

compared with baseline results of diesel operation. They found lower brake thermal efficiency for Jatropha methyl ester and its blends operation compared to diesel operation and higher brake specific energy consumption has been reported. Further lower HC, CO and CO₂ and smoke were observed to be with Jatropha biodiesel fuel. Higher NO_x emissions were observed with Jatropha biodiesel and its blend compared to Diesel operation.

Moniruzzaman m et al, (2017) [24]. Investigators expresses that without any scientific and technological backup, jathropha believed to be one of the most suitable biofuel feedstocks. They express that there has been no significant progress, and Jatropha did not contribute much in the energy scenario. Investigators suggests that production of Jatropha as a biofuel has been confronted with various challenges such as production, oil extraction, conversion and also its use as a sustainable biofuel. In their chapter, they disclose the challenges and possible remedy for the contribution in the biofuel industry.

Miftah Fekaduet et al (2019). [25]. In this paper, investigator reviewed nine oil yielding tree species and seeds of nine tree species including jathropha were collected to select best seed oil producer and its emission reducing capacity and land suitability. Seed oil was extracted by mechanical, hydraulic and chemical methods and stored at room temperature (25°C) and deep freeze (-20°C). Then, the tree species with highest oil yield was further studied for production of biodiesel, estimated end use emission as rural household energy and its land suitability.

2.2 COTTON SEED OIL AND ITS BIODIESEL:

Sinha et al, (2016) [26]. Production of biodiesel using waste cotton seed oil through transesterification has been reported. They found palmitic acid (27.76%) and linoleic acid (42.84%) and its molecular weight of the oil was 881.039 g/mol. They observed yield of 92% biodiesel when the reaction temperature, time, methanol/oil ratio and catalyst loading rate were 60 °C, 50 min, 12:1 and 3% (wt.%), respectively. They prepared high purified biodiesel and observed better engine performance. They found flash point and the fire point of the biodiesel were 128 °C and 136 °C, respectively. As far as Brake thermal efficiency of B10 is concerned, they observed 26.04% for maximum load; specific fuel consumption for diesel was 0.32 kg/kW h. Reduced carbon monoxide and hydrocarbon emissions and a marginal increase in nitrogen oxides emissions have been reported.

Rashid et al, (2011) [27]. measured the fuel properties of Cotton Seed Oil Methyl Ester (CSOME) and were compared with ASTM D6571 and EN14214. The cetane number of CSOME was 54.13. The measured properties kinematic viscosity, cloud point, flash point, and pour point were 4.07cSt, 7°C, 150 °C, and 6 °C respectively. The sulphur content and ash content were 0.011% and 0.013%, respectively. The density of CSOME was 875 kg/m³ and the calorific value was 45.2 MJ/kg. As per ASTM standards density is 870 kg/m³ and calorific value was 44.5 MJ/kg.

Nabi et al, (2008) [28]. studied optimization of biodiesel production and in different compression ignition characteristics. They produced biodiesel from Cottonseed oil (CSO) and transesterification resulted in maximum of 77% biodiesel with 20% methanol in presence of 0.5% sodium hydroxide. They observed engine t exhaust emissions including carbon monoxide (CO) particulate matter (PM) and smoke emissions and found reduced emission for all biodiesel mixtures. But they found slight increase in oxides of nitrogen (NO_x) emission with biodiesel mixtures.

Shrigiri et al, (2016) [29]. studied performance, emission and combustion characteristics of a diesel engine using two methyl esters: Biodiesel obtained from cotton seed oil and neem kernel oil. They used these biodiesels in a low heat rejection engine (LHR). They observed increased combustion chamber temperature by thermal barrier coating on piston face. Experimental investigations showed that, at peak load the brake thermal efficiency is lower by 5.91% and 7.07% and BSFC is higher by 28.57% and 10.71% for CSOME and NKOME in LHR engine, respectively when compared with conventional diesel fuel used in normal engine. They observed increase in NO_x emission in LHR engine along with slight increase in CO, smoke and HC emissions and found that the cylinder pressure for CSOME and NKOME in LHR engine were found very nearer to the diesel fuel in normal engine.

Rao et al, (2011) [30]. they studied properties of cotton seed oil methyl ester and problems in engine when operated with biodiesel. They analyzed various parameters such as brake thermal efficiency, specific fuel consumption and exhaust gas temperature. Their results showed that Biodiesel nblend (B25) showed closest performance to mineral diesel. The brake thermal efficiency for biodiesel and its blends is found to be slightly higher than that of diesel fuel at tested load conditions, but the exhaust gas temperature was increased with increase in load. They also noticed that reduced CO, CO₂ and HC emissions for all biodiesel mixtures. However, there was a slight increase in emission of oxides of nitrogen (NO_x) with use of biodiesel blends.

Bhargavi et al, (2018) [31]. studied biodiesel production using *Thespesia populnea* seed oil through rapid in situ transesterification. They investigated reaction parameters such as catalyst type and concentration, methanol to biomass ratio, co-solvent volume, temperature and agitation speed on conversion of oil into methyl esters. They found methyl ester conversion of 97.80% and achieved at 1.5wt% of KOH catalyst, 5.5:1 (v/w) methanol to biomass ratio, 25vol% tetrahydrofuran-co-solvent, 60°C and 500 rpm within 120min of reaction time.

Yücesu et al, (2006) [32] have investigated the biodiesel production using cottonseed oil through transesterification process. They have also investigated four-stroke, single cylinder, and air-cooled diesel engine performance using biodiesel. They conducted engine test at full load-and at different speed range. They found lower engine torque and power with cottonseed oil methyl ester compared diesel fuel and specific fuel consumption was found higher than that of diesel fuel by approximately 8–10%. Further they have reported that CO₂, CO, and NO_x emissions of cottonseed methyl ester were found lower than diesel operation.

Onukwuli et al, ((2017) [33] have produced biodiesel through transesterification of refined cotton seed oil with methanol and potassium hydroxide (KOH) as a catalyst. They studied physicochemical properties and studied engine performance. They studied influencing key parameters like reaction temperature; reaction time; catalyst concentration and methanol/oil molar ratio. They optimized process parameters using response surface methodology (RSM) and analysis of variance (ANOVA). They found results and found results obtained are in good agreement with published data. They found optimum yield of 96% with optimal conditions of methanol/oil molar ratio, 6:1; temperature, 55 °C; time, 60 min; and catalyst concentration, 0.6%.

Chen et al, (2007) [34] produced cottonseed oil methyl esters (biodiesel) using transesterification with methanol in the presence of solid acids as heterogeneous catalysts. They observed TiO₂-SO₄²⁻ and ZrO₂-SO₄²⁻ resulted in high activity for the transesterification. They found yield 90% under the conditions of 230°C, methanol/oil mole ratio of 12:1, reaction time 8 h and catalyst amount (catalyst/oil) of 2% (w).

Sundar K et al. (2019) [35]. Investigators expresses that developed countries are using edible oils to produce, are not sufficient to produce the biodiesel. Non edible oil is the right solution to overcome the problems related to the edible oils. In developing countries non edible oil plants are grown easily. Biodiesel originated from the nonedible plant, is more feasible compared to the alternative fossil fuel. Production of biodiesel using

cottonseed oil and rice bran oil appears to be a suitable substitute. The investigator reviewed the potentiality of the cotton seed oil and the rice bran oil in production of biodiesel.

2.3 CASTOR SEED OIL AND ITS BIODIESEL:

Literature pertaining to the utilization of castor oil methyl ester for diesel engine applications has been carried out and the same has been presented below.

Zareh et al, (2017) [36], produced biodiesel from castor oil biodiesel, coconut oil biodiesel and waste cooking oil biodiesel through transesterification process. Engine tests were conducted with blends of respective biodiesels with diesel fuel. Biodiesels blending ratios used are 5, 10, 20, and 30. They investigated performance and emission characteristics of turbocharged diesel engine at varying speed or load conditions. They found best results for blends of coconut oil biodiesel and waste cooking oil biodiesel compared to castor oil.

Prakash et al, (2018) [37] studied the effect of castor oil properties on the performance and emission characteristics of a diesel engine. They mixed alcohol in castor oil because of high Ricinoleic Acid leading to a mixture without any phase separation and also help in mixing with diesel. They found 40% castor oil, 30% diesel and 30% bioethanol blend is a optimum. They observed blend resulted thermal efficiency which is very close to diesel operation at full load operation. They found 6.11 g/kWh NO emission for blend whereas diesel is 8.17 g/kWh and 68% smoke opacity

Das et al, (2018) [38], studied combustion, performance and emission characteristics of a compression ignition engine operated on diesel and under three different blends of diesel and biodiesel (castor oil methyl ester, COME). For the blends operation combustion starts earlier and the rate of pressure rise during the rapid combustion phase is faster compared to that with diesel. They observed very little difference in the performance and emission (CO, HC and NO) characteristics of the engine with diesel-biodiesel fuel blends compared to diesel operation.

Akash et al, (2017) [39] investigated the effect of fuel properties on the engine performance. To have identical performance as that of diesel operation, during biodiesel operation existing engine require design modifications. They studied effects of fuel injection timing and injection pressure on the single cylinder four stroke diesel engine operated with B20 (diesel + castor biodiesel). They showed that B20 can be used without

any changes in fuel injection system and it results into better performance with acceptable emission levels.

Panwar et al, (2010) [40] investigated the effect of castor methyl ester (CME) on the performance and emission characteristics of four stroke, single cylinder variable compression ratio type diesel engine. They conducted tests at a constant speed of 1500 rpm and at different loads. They observed durability problems during the engine operation with neat vegetable oils when subjected to long term usage. Therefore, they have converted neat castor oil to biodiesel using transesterification method. They analyzed engine performance with different blends of biodiesel and compared with diesel operation. They found increased the brake thermal efficiency and reduced the fuel consumption with lower blends of biodiesel. The exhaust gas temperature increased with increasing biodiesel concentration. The results proved that the use of biodiesel (produced from castor seed oil) in compression ignition engine is a viable alternative to diesel.

2.4 LITERATURE SURVEY ON BIODIESEL AND KEROSENE BLENDED FUELS FOR DIESEL ENGINE APPLICATIONS:

Anjum et al, (2017) [41] studied the effect of the diesel-kerosene oil blend on the performance of single cylinder diesel engine. Blends of kerosene oil r with diesel were studied and are prepared in the ratio of 5%, 10% and 15% by volume and investigated. Experiments were conducted at different load conditions. They brake power, brake specific fuel consumption, brake mean effective pressure, fuel consumption. They found slightly lower fuel consumption for various blends and better performance blend of 95% diesel and 5 % kerosene. Further they observed similar brake power and brake mean effective pressure at lower load.

Dagaut and Cathonnet, (2006) [42] modeled the combustion of very complex hydrocarbon mixtures. They analyzed the combustion of kerosene with available kinetic data and surrogate mixtures. They have presented chemical kinetic modeling of kerosene combustion using model-fuels of variable complexity are also. Bilal (2015) investigated the combustion of diesel fuel and kerosene blends. They determined the performance and emission levels of kerosene blends. They presented results of combustion performance and gas emissions for a wide range of air-fuel equivalence ratios. They studied combustion efficiency and effect of blending of fuels on its performance. They found best results for blend of 75% kerosene and 25% diesel fuel when burned in the unit.

Wenming and Konga, (2017) [43]. investigated numerical study on the combustion and emission levels of a diesel engine operated on diesel-kerosene blend. They analyzed fuel blend ratio and fuel injection angle on the performance of the diesel engine. Increased maximum power output and lower carbon monoxide emission has been reported with kerosene addition. They have reported an fuel injection angle that gives the greater power output with low emissions.

Bayindir, (2010) [44]. investigated the performance and exhaust emissions of a compression ignition engine operated on cottonseed oil-kerosene blends. They studied effect of kerosene on the brake specific fuel consumption, exhaust gas temperature, and exhaust emissions values. Varied engine performance and brake specific fuel consumption and SO_x emissions were observed.

Kadhim, (2015) [45]. investigated the performance of kerosene blends in a diesel engine. They showed that reduced BSFC by 14.1 % and 20.1% when engine fueled with 10 and 20 % kerosene in a diesel fuel. But they observed increased exhaust gas temperature, BTE, CO₂ and NO_x levels when engine was operated with 10 and 20 % kerosene blends.

Bilal A. Prakask, (2015) [46] He conducted experiments on horizontally positioned combustion chamber using diesel fuel, kerosene and their blends. He aimed to determine the combustion performance and gas emission of diesel fuel, kerosene and various mixtures of diesel fuel and kerosene. Tests were conducted for combustion performance and gas emissions for a wide range of air-fuel equivalence ratios. Stated that some improvements in exhaust gas emission and combustion efficiency were obtained upon using mixtures of fuels. The best results were obtained when a fuel blend of 75% kerosene and 25% diesel was prepared and burned in the unit.

Rubiat Mustak and Tanjim Ahmed, (2018) [47]. Conducted investigations using various blends of kerosene and palm oil with diesel. At first kerosene alone is blended with diesel in various ratios and the effect of blending was studied on properties. After that the palm oil alone with diesel in various ratio and effect of blending on properties studied. At last palm oil and kerosene together blended with diesel fuel in equal portion and the change in various fuel properties was studied. The effect of blending palm oil and kerosene alone with diesel is compared with the effect of blending palm oil and kerosene together with diesel in terms of fuel properties. In order to compare the effects various blends fuel properties were measured. The experimentation mainly concentrated on properties lower heating value (LHV) or lower calorific value (LCV) and density for various above said blends of diesel for comparison purposes. Stated that from the

investigation it is found that blends of vegetable oils with diesel has higher density than diesel fuel where as it is lower with blends with paraffin is considered. Also, stated that that blending of vegetable oils with diesel fuel results in low L.H.V or L.C.V when compared with diesel. Suggested that these investigations will serve as a guideline for young researchers who wish to study the effect of blending vegetable oils and paraffin with diesel fuel.

Azad et al., 2013[48] conducted comprehensive study of DI diesel engine performance using biodiesel from mustard oil blends with kerosene. The vegetable oil without transesterification reaction have been blended with kerosene oil by volume in some percentage like 20%, 30%, 40% and 50% which have been named as M20 (20% mustard, 80% kerosene), M30 (30% mustard, 70% kerosene), M40 (40% mustard, 60% kerosene) and M50 (50% mustard, 50% kerosene). The properties of the bio-fuel blended with kerosene have been tested in the laboratories with maintaining different ASTM standards. Several engine parameters like bsfc, bhp, break mean effective pressure, exhaust gas temperature, lube oil temperature, sound level etc. were determined for bio-diesel blends with kerosene and compared with that of diesel fuel.

Hasan Bayindir 2017 [49], studied the effect of using different blended cotton oil-kerosene (COK) on engine power, torque, brake specific fuel consumption and brake specific energy consumption were studied. Experimental results showed that engine power, torque and brake specific fuel consumption was slightly different from the diesel usage. However, using COK fuel for so long in unmodified diesel engine can partly cause injection system faults and carbon soot problems.

2.5 KEROSENE AND PETROL BLENDED DIESEL FUELS FOR ENGINE OPERATION:

Anjum et al., 2017[50]. conducted an experimental analysis to check the diesel engine performance using various blends of kerosene with mineral diesel. Different blends of kerosene oil together with diesel in the ratio of 5%, 10% and 15% by volume and investigated under the different load conditions in a CI engine. The outcomes under various parameters were found to be closer to diesel fuel. Different engine parameters such as brake power, brake specific fuel consumption, brake mean effective pressure, fuel

consumption rate, exhaust gas temperature etc. have been determined and these were compared with diesel fuel.

Kadhim 2015[51], conducted experimental study to evaluate the effect of blending kerosene (by different volume) with diesel fuel on the performance and emissions of a single cylinder 4-stroke air cooled DI diesel engine running at fixed speed with different loads (torques). Two levels of blend 10% and 20% of kerosene blending by volume with diesel fuel were named K10 and K20 respectively, while pure diesel was considered as a baseline and named D. Results showed that the bsfc has been reduced by 14.1% and 20.1% when engine fueled with K10 and K20 respectively at low load compared with pure diesel. Exhaust gas temperature, BTE, CO₂ and NO_x concentration have been increased when engine fueled with K10 and K20 instead of diesel fuel(D). These results indicted the possibility of using blending kerosene (by 10% and 20% by volume) with diesel fuel without any modification in the engine

2.6 GENERAL VEGETABLE OIL AND BIODIESEL FUELED ENGINES

Rehman H *et al*, (2004) [52] conducted a series of experiments on a single cylinder, four-stroke C.I. engine operated on preheated Karanja and Neem oils. Initially, they estimated viscosities of Neem, Karanja oils and their biodiesels and compared with neat diesel. Afterwards they conducted the experiments on DI compression ignition engine fueled with above mentioned methyl esters. They have evaluated that there was an increase in torque and brake power whereas decrease in specific fuel consumption and exhaust emissions for Karanja oil methyl ester blends with diesel of proportion B20 and B40.

Atabani *et al*, (2013) [53] highlighted the use of non-edible oils as biodiesel feed stocks. This paper provides exhaustive review of several aspects related to the various feed stocks available, advantages of non-edible oils, problems in their exploitation, fatty acid composition profiles, oil extraction techniques, biodiesel production, standards used, and characterization of biodiesels carried out. Performance and emission characteristics of engines fueled with biodiesels have also been presented. Huge scope for biodiesel production has been highlighted.

2.7 USE OF KEROSENE OR GASOLINE AS ADDITIVE FOR STRAIGHT VEGETABLE OILS:

Kerosene or gasoline is basically added to the diesel and biodiesels to lower the viscosity. It is lighter in weight compared to diesel. Therefore, these are mixed with straight vegetable oils to lower the viscosity of vegetable oils.

Kerosene is a fuel and its properties lie in between diesel and petrol. Kerosene viscosity is 1.4 -1.6 cSt (at 40°C), whereas gasoline viscosity is between 1.1 to 1.3 cSt (40°C) but diesel has 3.4 cSt (40°C). kerosene alone cannot be used as fuel in diesel engines because it damages the fuel injection pump and leakages leading to lower injection pressure. Whereas gasoline alone can be used as fuel in SI engines. When kerosene or gasoline is blended with vegetable oils within the limit it results into better engine performance but beyond 20% there can be separation and leading to improper spray characteristics i.e. improper fuel penetrate into the compressed air due to production of small droplets. However, mixing of kerosene or gasoline with straight vegetable oils seems to be better due to higher thermal values obtained. The viscosity of straight vegetable oil blends lowers due to lower viscosity of kerosene or gasoline and have higher heating values.

Viscosity and density of straight vegetable oil decreases when this was blended with kerosene or gasoline. The mass of fuel pumped differs when kerosene or gasoline blend was used as fuel. This affects combustion process due to differences in the atomization. Kerosene or gasoline addition to vegetable oils improves the atomization blend fuel. To use kerosene or gasoline blend as fuel must meet specification requirement of diesel fuel ranging from 0.815 to 0.870. Addition of kerosene or gasoline to vegetable oil decreases the flash point. The flash point of kerosene or gasoline blend vegetable oil blends meets the specification of diesel. Further, cloud point and pour point were also decreases with increased quantity of kerosene or gasoline in straight vegetable oil. Cetane number decreases as the kerosene or gasoline quantity increase in the blend. In addition, kerosene or gasoline lowers the cold flow characteristics of vegetable oils.

2.7 SUMMARY OF LITERATURE REVIEW

In summary, the literature pertaining to operation of diesel engine fueled with Cotton seed oil, Jatropha seed oil and Castor seed oil and their blends in single fuel mode of engine operation suggests the following information:

- Vegetable oils are more suited to diesel engine operation without any modification for a short period of operation.
- Transesterification of vegetable oils is an effective method of reducing viscosity and thereby improving their performance.
- Vegetable oil blends can be effectively used as feasible alternative fuel to diesel.
- Different engine parameters such as injection timing, injector opening pressure have varied to improve the diesel engines performance when fueled with biodiesels. However, the work is mainly restricted to determination of performance characteristics of diesel engine fueled with the blended vegetable oils

It is evident that engine operation with blended Cotton seed, Jatropha and Castor seed oils with gasoline or kerosene can eliminate use of petroleum. Literature survey indicates that the above methods have so far not been investigated in detail as regards to blended vegetable oil fueled diesel engine and to study the performance. Therefore, the present work aims at studying and comparing these options on a diesel engine fueled with blended vegetable oil in order to analyze their potentiality and suitability.

CHAPTER 3

MATERIALS AND METHOD

The following section describes preparation of blended vegetable oil samples properties and experimental setup. It also indicates the samples chosen for conducting performance test.

3.1 METHODOLOGY

1. First non-edible Jatropha, Castor and Cotton seeds available places are identified. The seeds of required quantity Castor seeds collected from a place called Arsinegle Ethiopia, Jathropha seeds collected from Gadeo near to Dilla and Cotton seeds collected from Awash 7, Ethiopia. All the seeds were collected through farmers and local boys.
2. Oil extracted in Mekuria Edible oil making small scale factory, Adama Kebele 20, near to Abader Hotel. Since the seeds are none-edible, used old mechanical grinder to extract the oil. The extraction rate was poor and full of impurities that why purification was done in India.
3. After oil is extracted gasoline and kerosene procured from gas stations.
4. 10 samples of blended cotton seed oil with gasoline is prepared with mixing proportion is in steps of 3% gasoline
5. Again 10 samples of blended cotton seed oil with kerosene is prepared with mixing proportion is in steps of 3% kerosene.
6. Step 4 and 5 is repeated for Jathropha and castor seed oils.
7. Viscosity, flash point and fire point of each of these samples determined
8. Two samples chosen for further experimentation based on the viscosity which is closer to petroleum diesel.
9. It is found to be cottonseed oil blended with gasoline (21%) and Cotton seed oil blended with kerosene (21%).
10. Calorific value of these selected fuel samples are determined using calorimeter.
11. Experimental test rig consisting of single cylinder CI engine coupled with dynamometer identified.
12. Operating the engine for 10 hours and simultaneously performance test (brake thermal efficiency and fuel consumption) conducted initially by fueling diesel. After completion of 10 hours of running, engine is replaced with new set of cylinder head, piston and valves.
13. Repeating the same procedure by fueling the engine with COB with gasoline and kerosene.
14. Finally, performance of engine compared for diesel and COB with gasoline and kerosene. Also soot deposition on piston and cylinder head are compared for diesel and blended fuels.

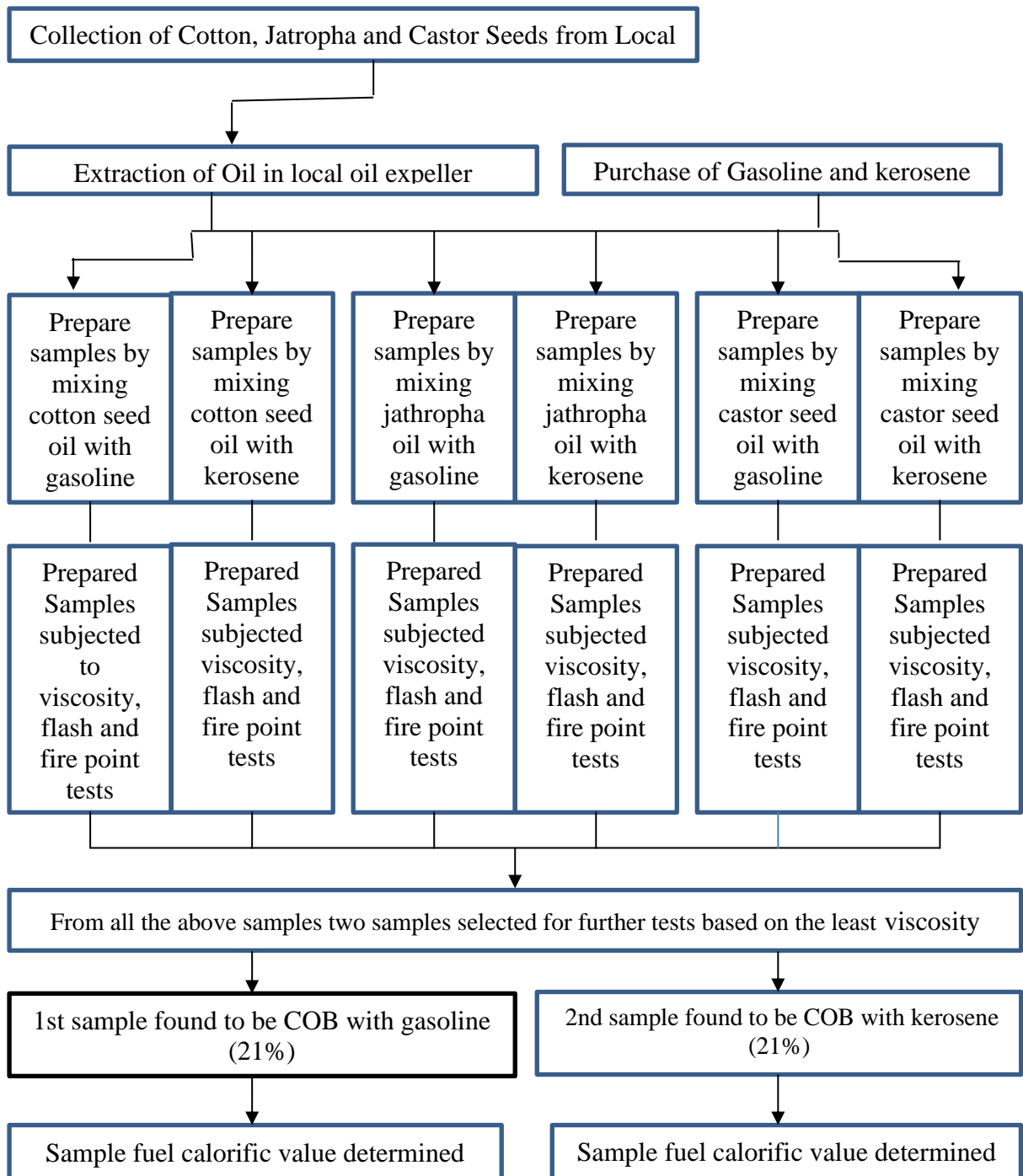


Figure 3.1 - Block diagram of material procurement and processing.

3.1 FUELS USED IN PRESENT WORK

Direct use of Vegetable oils of Cotton seed, Jatropha seed and Castor seed as a fuel for diesel engine can cause particle agglomeration and injector fouling due its low volatility and high viscosity. It is therefore necessary to reduce the viscosity this can be done by blending these oils with gasoline and kerosene in different proportions. Hence the samples of blended above-mentioned vegetable oils (3% of gasoline in progressive order

and 3% of kerosene in progressive steps) are prepared as shown in figure. The mixing of additives is in the proportion of 3% of base oil in progressive steps.



Figure 3.2 Castor, Cotton, and Jatropha seed oil respectively

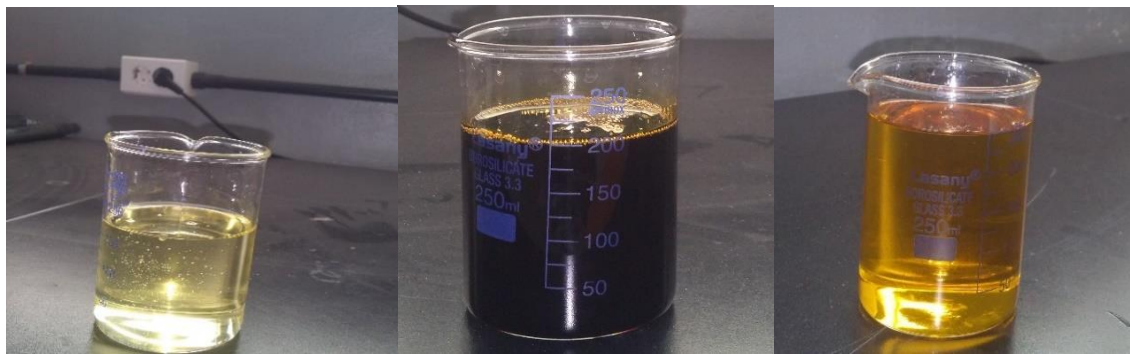


Figure 3.3 Cotton, Castor, Jatropha seeds oils with Gasoline

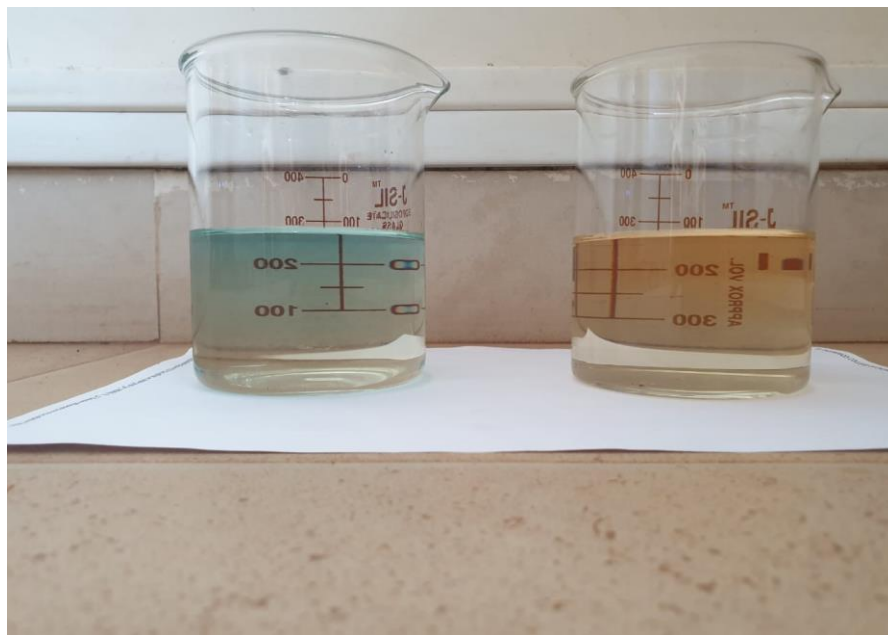


Fig 3.4 Castor oil blended with kerosene and gasoline

The properties like viscosity, flash, and fire point of all the samples of blended vegetable oils were determined in material testing laboratory of Don Bosco Institute of Technology Bangalore, India.

The kinematic viscosity has been determined by red wood viscometer at 40°C whereas flash and fire point is determined by open cup Cleveland apparatus the images of the apparatus are shown below.



Figure 3.5 Redwood viscometer



Figure 3.6 Cleveland open cup apparatus

The following properties have been determined for different vegetable oil blends sample. The details of percentage of mixing of gasoline and kerosene for jatropha, cotton seed and castor seed oils and their respective properties are shown in the table.

Table 3.1: CASTOR SEED OIL + GASOLINE

S.No	Castor Seed Oil (ML)	Gasoline (ML)	Kinematic Viscosity (Centi Stokes)	Flash Point °C	Fire Point °C
1	200	0	9.08	193	198
2	200	6 (3 %)	8.91	164	173
3	200	12(6%)	8.58	156	167
4	200	18(9%)	8.45	149	158
5	200	24(12%)	8.17	139	148
6	200	30(15%)	7.97	125	134
7	200	36(18%)	7.82	109	119
8	200	42(21%)	7.54	102	112
9	200	48(24%)	7.34	84	94

Table 3.2: COTTON SEED OIL + GASOLINE

S.No	Cotton Seed Oil (ML)	Gasoline (ML)	Kinematic Viscosity (Centi Stokes)	Flash Point °C	Fire Point °C
1	200	0	7.43	167	177
2	200	6 (3 %)	7.92	140	150
3	200	12(6%)	7.59	133	142
4	200	18(9%)	7.23	126	137
5	200	24(12%)	7.05	114	125
6	200	30(15%)	6.85	103	113
7	200	36(18%)	6.60	96	107
8	200	42(21%)	6.44	83	94
9	200	48(24%)	6.41	67	78

Table 3.3: JATROPHA SEED OIL + GASOLINE

S.No	Jatropha Seed Oil (ML)	Gasoline (ML)	Kinematic Viscosity (Centi Stokes)	Flash Point °C	Fire Point °C
1	200	0	8.25	187	196
2	200	6 (3 %)	8.17	151	161
3	200	12(6%)	8.09	140	150
4	200	18(9%)	7.95	134	144
5	200	24(12%)	7.67	120	130
6	200	30(15%)	7.43	111	121
7	200	36(18%)	7.01	102	112
8	200	42(21%)	6.77	88	98
9	200	48(24%)	6.47	77	87

Table 3.4: CASTOR SEED OIL + KEROSENE

S.No	Castor Seed Oil (ML)	Kerosene (ML)	Kinematic Viscosity (Centi Stokes)	Flash Point °C	Fire Point °C
1	200	0	9.08	193	198
2	200	6 (3 %)	8.58	160	170
3	200	12(6%)	8.42	152	162

4	200	18(9%)	8.25	145	155
5	200	24(12%)	8.00	134	144
6	200	30(15%)	7.79	120	130
7	200	36(18%)	7.64	105	114
8	200	42(21%)	7.34	98	107
9	200	48(24%)	7.10	80	92

Table 3.5: COTTON SEED OIL + KEROSENE

S.No	Cotton Seed Oil (ML)	Kerosene (ML)	Kinematic Viscosity (Centi Stokes)	Flash Point °C	Fire Point °C
1	200	0	7.43	167	177
2	200	6 (3 %)	7.43	134	143
3	200	12(6%)	7.26	128	139
4	200	18(9%)	7.01	121	130
5	200	24(12%)	6.85	108	117
6	200	30(15%)	6.68	98	106
7	200	36(18%)	6.52	90	101
8	200	42(21%)	6.47	77	88
9	200	48(24%)	6.30	62	73

Table 3.6: JATROPHA SEED OIL + KEROSENE

S.No	Jatropha Seed Oil (ML)	Kerosene (ML)	Kinematic Viscosity (Centi Stokes)	Flash Point °C	Fire Point °C
1	200	0	8.25	187	196
2	200	6 (3 %)	8.12	145	155
3	200	12(6%)	7.99	134	144
4	200	18(9%)	7.51	128	138
5	200	24(12%)	7.18	114	123
6	200	30(15%)	6.93	105	114
7	200	36(18%)	6.60	96	107
8	200	42(21%)	6.53	82	93
9	200	48(24%)	6.19	70	82

As per literature survey the vegetable oil and the additives such as gasoline and kerosene will not mix thoroughly when it is feeding to engines as fuel hence, best sample is chosen for 21% of additive mix. As per the obtained property values of kinematic viscosity from the above tables the following combination is been selected for further performance test i) Cotton seed oil + 21% Gasoline (6.44 Centi Stokes) ii) Cotton seed oil + 21% kerosene (6.47 Centi Stokes).

3.2 PROPOSED FUEL PRODUCTION

Locally available cotton seed can be used for producing oil using portable oil expeller. The oil produced need to filtered with fine mesh. Then blended oil fuel can be prepared by mixing 1 litre of cotton seed oil with 0.21 litre of gasoline. This blended fuel can be used directly as a fuel for water pump set engine the only care should be taken starting of the engine should use diesel fuel till the engine warms up then blended vegetable oil can be used as fuel to run water pump engine.

3.3 EXPERIMENTAL SET UP

Testing facility was not available in Ethiopia, hence, the test was conducted at IC engine laboratory, mechanical engineering department, KLE Technological University (Earlier it was BVB Engineering College), Hubli, India, on single cylinder DI engine test rig coupled with eddy current dynamometer on request The engine tests were conducted on a four-stroke single cylinder water-cooled direct injection compression ignition engine with a displacement volume of 662 cc, compression ratio of 17:1, developing 5.2 kW at 1500 rev/min. Figure 3.10 shows the arrangement of the experimental set up. The specifications of the engine are given in Appendix-1. The tests were conducted by running the engine at rated speed of 1500 rev/min. The engine had a conventional fuel injection system. The injector opening pressure and the static injection timing as specified by the manufacturer was 205 bar and 23° bTDC respectively. However, experimentation carried out with manufacturer recommended injection timing and pressure. The injector used had three orifices each of 0.3 mm diameter is used as shown in the Figure 3.13 and 3.14. The centrifugal governor of the engine was used to control the engine speed. The engine was provided with a hemispherical combustion chamber with overhead valves operated through push rods. Cooling of the engine was accomplished by circulating water through the jackets on the engine block and cylinder head.

First diesel fueled CI engine operated for 10 hours and simultaneously performance and smoke emission tests conducted, the procedure is repeated with the same CI engine fueled with blended cotton seed oil with gasoline (21%) and blended cotton seed oil with kerosene (21%) separately. Ten hours of engine running with diesel and other COB fuels is to observe and compare soot deposition on parts of engine. The performance test is to obtain BTE and BSFC parameters. Smoke emission tests conducted to obtain smoke emission data of each fuel. Performance and smoke emission tests conducted with different loads keeping constant speed with injector pressure of 205 bar and injector hole of 0.3 mm as supplied by the manufacturer. Following block diagram shows experimental set up and stages of tests carried out.

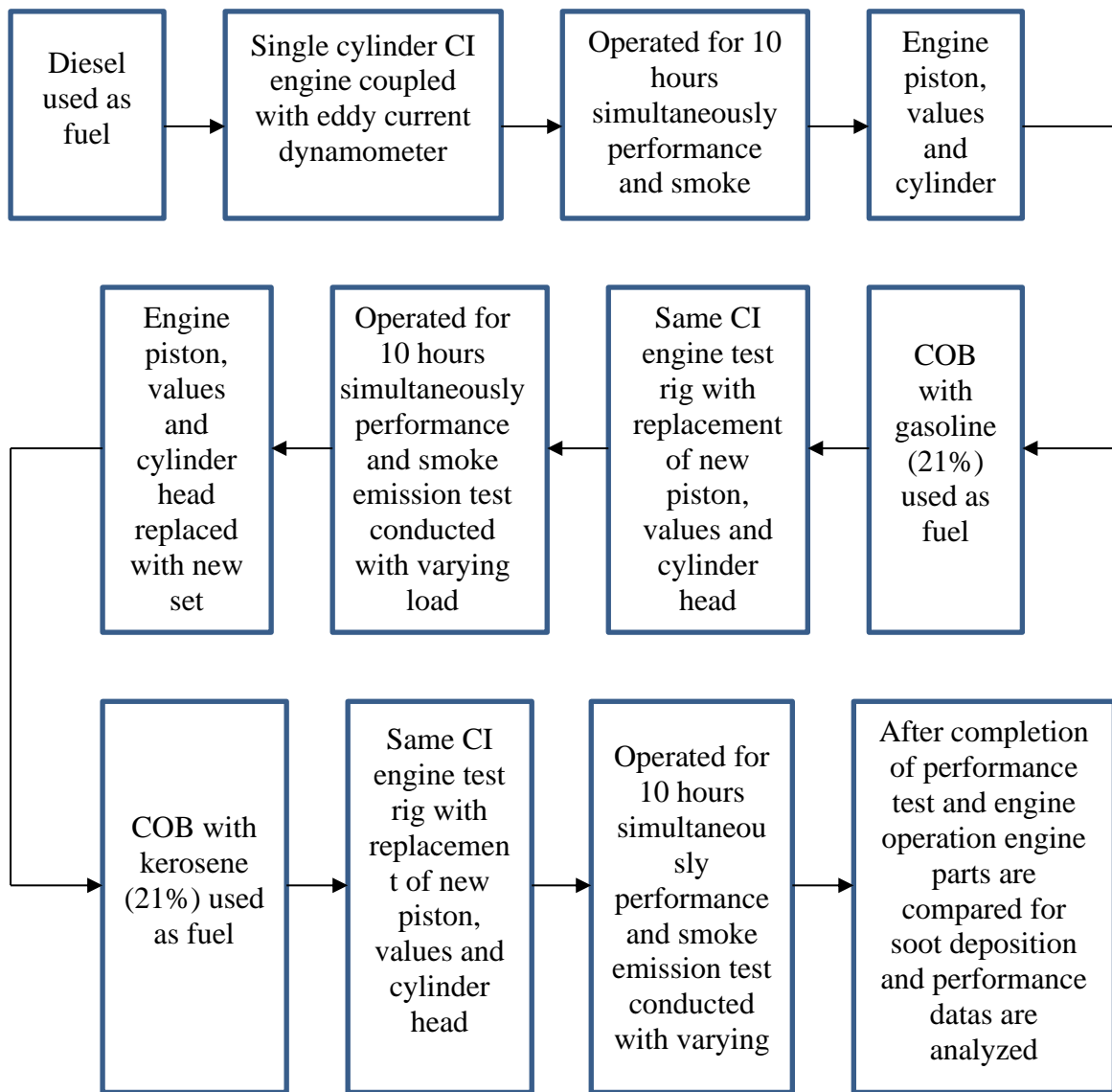


Figure 3.7- Block Diagram of Experimental Set up



Figure 3.8 single cylinder four stroke DI compression ignition engine test rig.



Figure 3.9 Injector spray from orifice



Fig 3.10 Injectors containing 3 Hole

3.4 LOAD AND SPEED MEASUREMENTS

The engine was directly coupled to an eddy current dynamometer that permitted engine motoring fully or partially. The engine and dynamometer were interfaced to a control panel. The specifications of the dynamometer are given in Appendix-4. A photo sensor along with a digital speedometer was used to measure the speed of the engine. The voltage pulses from the sensor are sent to the digital speedometer for pulse conversion and display of the engine speed with an accuracy of 1 rev/min.

3.5 AIR FLOW MEASUREMENT

Airflow rate was measured using air box method. The air is drawn into a large tank through an orifice whose diameter and coefficient of discharge are known. The outside air is flowing continuously through the orifice with constant velocity. This velocity depends upon the difference of pressure between the air in the tank and the atmosphere air. This pressure difference is measured by a U- tube manometer. One limb of U-tube manometer is connected to the inside of chamber while the other end is open to the atmosphere. The measured pressure difference is used to calculate the air flow rate to the engine.

3.6 FUEL SUPPLY AND MEASUREMENT

Fuel Flow rate to the engine was measured on volume basis using a burette and stopwatch. The system consists of two spherical glass bulbs having 100 cc and 200 cc capacities respectively. They are connected by three- way cock so that one may feed the engine while the other being filled.

3.7 TEMPERATURE MEASUREMENT

Temperature of the exhaust gas was measured with Chromel Alumel (K-Type) thermocouples. A digital indicator with automatic room temperature compensation facility was used. The thermocouple was calibrated periodically with the help of certified instrument calibration agencies. Temperature readings were taken at locations such as cooling water inlet, cooling water out let, inside cylinder surface and exhaust gas out let for each load interval.

3.8 MEASUREMENT OF SMOKE

Exhaust smoke density was measured with the help of Hartridge Smoke meter shown in Figure 3.15. The smoke meter works on the principle of comparative basis. It contains two dimensionally and optically similar tubes. The reference tube is connected to the clean air blower. Air is drawn from the clean air inlet through a damper. The smoke tube is connected to the smoke inlet via the smoke bypass valve. This inlet track contains a temperature sensor, moisture trap and has a pressure relief valve-controlled outlet, a pick off for the manometer connection and a vane at the tube entry.

The light source and photoelectric cell are each mounted on an arm pivoted on each end of a spring-loaded control shaft, which is operated by a control knob. The opacity of the smoke sample was compared to a clean air sample by first taking reading through the clean air tube to set the zero, then moving the light and photoelectric cell to the smoke tube for an instantaneous comparative reading of the opacity of the tube sample. The specifications of the Hartridge Smoke meter are given in Appendix-7.



Figure 3.11 Hartridge Smoke meter

3.9 EXPERIMENTS CONDUCTED

All experiments were carried out at the rated speed of 1500 RPM at different load conditions. Readings were always taken by starting the engine with diesel fuel and then switching over to the selected blended vegetable oil (cotton seed oil + 21% gasoline & Cotton seed oil + 21% kerosene) fuel and at the completion stage again the engine is shifted back to the diesel mode. The readings were taken once the engine stabilized with the selected blended vegetable oil. To obtain accuracy in readings for each experiment, 3 sets of readings were taken and averaged out. The temperature of cooling water at exit was maintained at 70°C throughout the test period to ensure stability of the engine. Exhaust gas analyzers were switched on and allowed to stabilize before the measurements were taken. Instruments were periodically calibrated. The test matrix is shown in Table 4.1.

Table 3.7 Test matrix for Experimentation

% LOAD	FUEL	REQUIREMENT
Maintained at 0%, 20%, 40%, 60%, 80% and 100% Full load	1. Diesel 2 Blended Cotton seed oil with gasoline (21%) 3 Blended cotton seed oil with kerosene (21%)	Base line data generation with manufacturer specified engine condition.

A single cylinder four-stroke compression ignition engine was selected to conduct the experiment. The engine manufacturer's set parameters are: Injection timing at 23° bTDC, Injector opening pressure (IOP) at 205 bar. The injector was having 3 holes of 0.3 mm diameter. Initially, the experiment was conducted using conventional diesel later repeating the experiment for blended Cotton seed with gasoline and blended Cotton seed oil with kerosene at the rated speed of 1500 rev/min and IOP of 205 bar (manufacturer set IOP) under variable load conditions. Next, the engine is continued to run for 10 hours with blended cottonseed oil with gasoline.

CHAPTER 4

RESULT AND DISCUSSIONS

4.1 PERFORMANCE AND SMOKE TESTS DATA TABLE

The following tables show the mean readings obtained during performance and smoke tests. Data tables are shown in table no 4.1, 4.2 and 4.3 for diesel, cotton seed oil blended with gasoline and for cotton seed oil blended with kerosene fuels respectively. The tests were conducted three times for each fuel and mean reading were considered for result analysis.

Table 4.1 Test readings for diesel fuel

Fuel: Diesel.

C.R: 17.5.

IOP: 205 bar.

Nozzle diameter: 0.3 mm.

Room temperature: 28°C.

Engine: Normal

Sl No	Load (W) in Kg	Speed (N) in rpm	Time taken for 25 cc fuel consumption (t) Sec	Mass flow rate of fuel (m_f) in kg/sec	Manometer reading (h) mm	Mass flow rate of air (m_a) kg/s	Exhaust gas temperature in °C
1	0	1500	0	0	82	0.00819	158
2	4	1500	139	0.00015116	76	0.007889	212
3	8	1500	104	0.00020155	72	0.007678	278
4	12	1500	84	0.00025020	70	0.007571	334
5	16	1500	68	0.00030958	68	0.007462	403
6	20	1500	52	0.00040310	62	0.007125	510

Sl No	Brake Power in (BP) kW	Peak Pressure in bar	Brake thermal Efficiency (BTE) in %	Brake Specific fuel Consumption (BSFC) in kg/kW hr	Smoke Emission in HSU	Ignition Delay in degree CA	Combustion Duration in degree CA
1	0	57	0	-	22	12.8	26
2	1.04	60	16	0.523	24	12.2	28
3	2.08	63	24	0.349	32	11.4	31
4	3.12	69	29	0.289	38	10.6	34
5	4.16	74	31.25	0.268	46	9.9	38
6	5.2	84	30	0.279	66	8.9	43

Density of diesel = 840 kg/m³

Calorific Value of Diesel = 43000 kJ/kg

Table 4.2 Test reading for cotton seed oil blended with gasoline (CO + 21% gasoline)

Fuel: CO+21% gasoline.

CR: 17.5.

IOP: 205 bar

Nozzle diameter: 0.3 mm.

Room temperature: 30°C

Engine: Normal

Sl No	Load (W) in Kg	Speed (N) in rpm	Time taken for 25 cc fuel consumption (t) Sec	Mass flow rate of fuel (m_f) in kg/sec	Manometer reading (h) mm	Mass flow rate of air (m_a) kg/s	Exhaust gas temperature in °C
1	0	1500	-	-	80	0.008093	162
2	4	1500	114	0.00019433	74	0.007784	216
3	8	1500	88	0.00025099	70	0.007571	282
4	12	1500	72	0.00030964	68	0.007462	338
5	16	1500	57	0.00038765	66	0.007351	408
6	20	1500	43	0.00051060	60	0.007009	518

Sl No	Brake Power in (BP) kW	Peak Pressu re in bar	Brake thermal Efficiency (BTE) in %	Brake Specific fuel Consumption (BSFC) in kg/kW hr	Smoke Emission in HSU	Ignition Delay in degree CA	Combustion Duration in degree CA
1	0	52	0	-	33	13.3	29
2	1.04	55	13.4	0.673	37	12.5	33
3	2.08	59	20.75	0.434	41	12.20	35
4	3.12	65	25.23	0.357	46	11.20	38
5	4.16	70	26.87	0.335	56	10.60	43
6	5.2	78	25.50	0.353	78	9.40	46

Density of CO + 21% Gasoline = 884.4 kg/m³

Calorific Value of CO + 21% Gasoline = 39938 kJ/kg

Table 4.3 Test readings for Cotton seed Oil blended with kerosene (CO + 21% kerosene)

Fuel: CO+21% kerosene.

C.R:17.5.

IOP:205 bar.

Nozzle diameter: 0.3 mm.

Room temperature:30°C.

Engine: Normal

Sl No	Load (W) in Kg	Speed (N) in rpm	Time taken for 25 cc fuel consumption (t) Sec	Mass flow rate of fuel (m_f) in kg/sec	Manometer reading (h) mm	Mass flow rate of air (m_a) kg/s	Exhaust gas temperature in °C
1	0	1500	-	-	78	0.007992	165
2	4	1500	116	0.00019451	72	0.007678	219
3	8	1500	88	0.00025681	68	0.007462	285
4	12	1500	71	0.00031714	66	0.007351	352
5	16	1500	56	0.00040014	64	0.007239	415
6	20	1500	44	0.00050694	62	0.007125	518

Sl No	Brake Power in (BP) kW	Peak Pressu re in bar	Brake thermal Efficiency (BTE) in %	Brake Specific fuel Consumption (BSFC) in kg/kW hr	Smoke Emission in HSU	Ignition Delay in degree CA	Combustion Duration in degree CA
1	0	50	0	-	34.5	13.5	30
2	1.04	53	13.5	0.673	39	13	34
3	2.08	57	20.45	0.444	43.5	12.3	36
4	3.12	63	24.84	0.366	48	11.4	39
5	4.16	68	26.25	0.346	58.5	11	44
6	5.2	76	25.90	0.351	81	9.6	47

Density of CO + 21% Kerosene = 840 kg/m³

Calorific Value of CO + 21% Kerosene = 39606 kJ/kg

4.2 EFFECT OF COTTON SEED OIL BLEND (COB)

This section gives the analysis of cottonseed oil blended with gasoline and kerosene. Also give an idea how it influences on the brake thermal efficiency, brake specific fuel consumption, smoke emission and soot deposition

4.2.1 BRAKE THERMAL EFFICIENCY

The effect of blending COB with kerosene and gasoline on brake thermal efficiency for single fuel operation when fueled with diesel and COB is shown in Fig.5.1. The highest brake thermal efficiency is obtained with COB blended with gasoline followed by kerosene. Brake thermal efficiency values were lower for COB as compared to diesel.

The decrease in brake thermal efficiency for COB might be attributed to lower energy content of the fuel and higher fuel consumption required for the same power output. Due to higher viscosity of COB the formation of the mixture and subsequent combustion were poorer than diesel.

The maximum brake thermal efficiency for COB is 26.87% as compared to 31.25 % for diesel. However, by blending COB with 21% volatile fuels of gasoline and kerosene respectively an improvement in brake thermal efficiency is obtained. COB being common blending with gasoline resulted into higher BTE followed by kerosene.

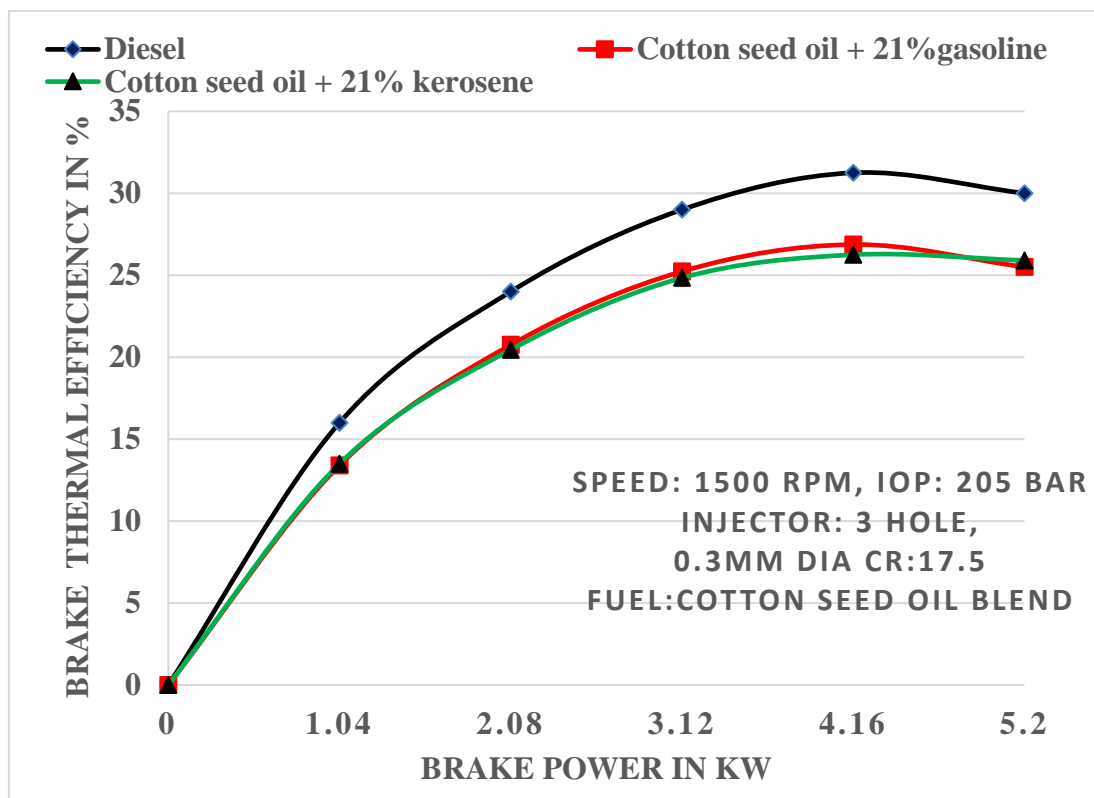


Fig. 4.1 Effect COB on Brake Thermal Efficiency

4.2.2 SMOKE OPACITY

The effect of blending Cotton seed oil with kerosene and gasoline on smoke emission for single fuel operation is shown in Fig.5.2. Smoke opacity for both fossil diesel and renewable fuel Cotton seed oil and its blending with volatile fuels of gasoline, kerosene respectively increased with increased brake power. Increased quantity of both pilot fuels that are injected in the engine cylinder results into increased smoke emissions. Formation of smoke is basically a process of conversion of molecules of hydrocarbon fuels into particles of soot. The greater smoke opacity observed with COB compared to diesel fuel

could be mainly due to emission of higher molecules of hydrocarbons and particulate associated. Comparatively heavier molecular structure of COB due to its higher viscosity and density could also be responsible for the higher smoke emissions. For the same loading operation lower volatility and lower energy content of the vegetable oil compared to diesel operation results into varied air-fuel ratio and hence incomplete combustion with higher smoke emissions. The smoke emissions decreased with 21% blending of gasoline followed by kerosene respectively. It is a clear indication of relatively better combustion of fuel air mixture. The reasons for incomplete combustion are incorrect air-fuel ratio and improper mixing.

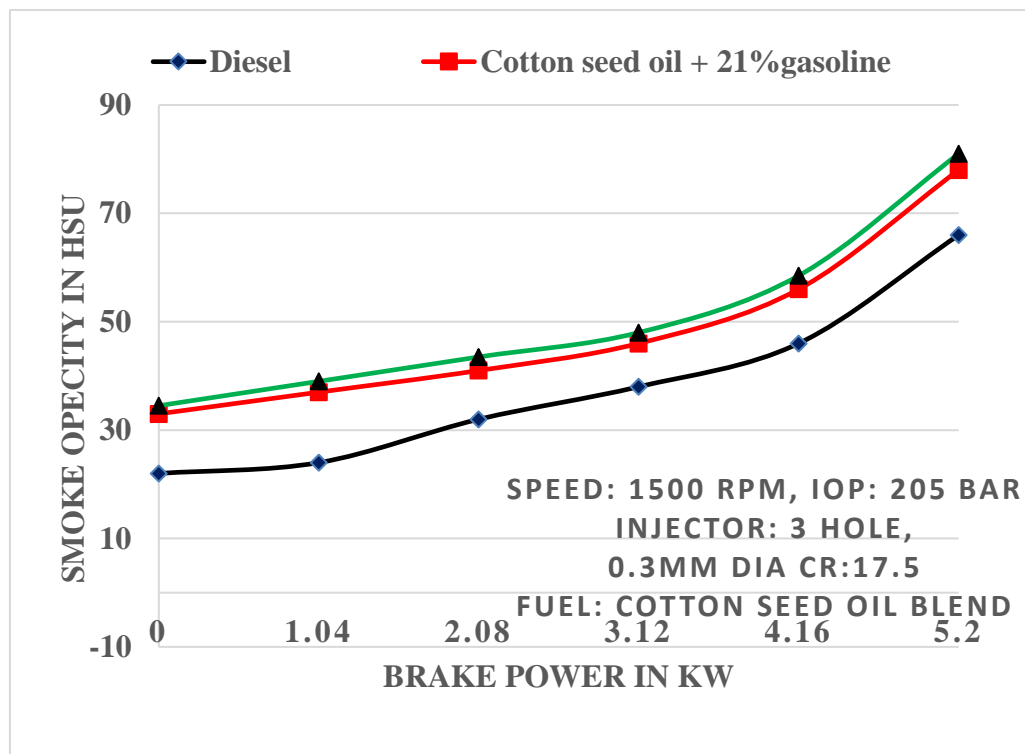


Fig. 4.2 Effect of COB on Smoke opacity

4.2.3 SPECIFIC FUEL CONSUMPTION:

The effect of blending COB with kerosene and gasoline on specific fuel consumption (SFC) for single fuel operation when fueled with diesel and COB is shown in Fig.5.3. The SFC is obtained with COB blended with gasoline and kerosene are almost equal. SFC values were higher for COB as compared to diesel. The Increase in SFC for COB might be attributed to lower energy content and due to incomplete combustion to an extent of the fuel and higher fuel consumption required for the same power output. Due to higher

viscosity of COB the formation of the mixture and subsequent combustion were poorer than diesel.

The minimum SFC for COB is 0.350 kg/kW-hr as compared to 0.270 kg/kW-hr for diesel. However, by blending Cotton seed oil with 21% volatile fuels of gasoline and kerosene respectively an lowering in SFC is obtained. Cotton seed oil being common blending with gasoline and kerosene resulted into lower SFC for both blended fuels.

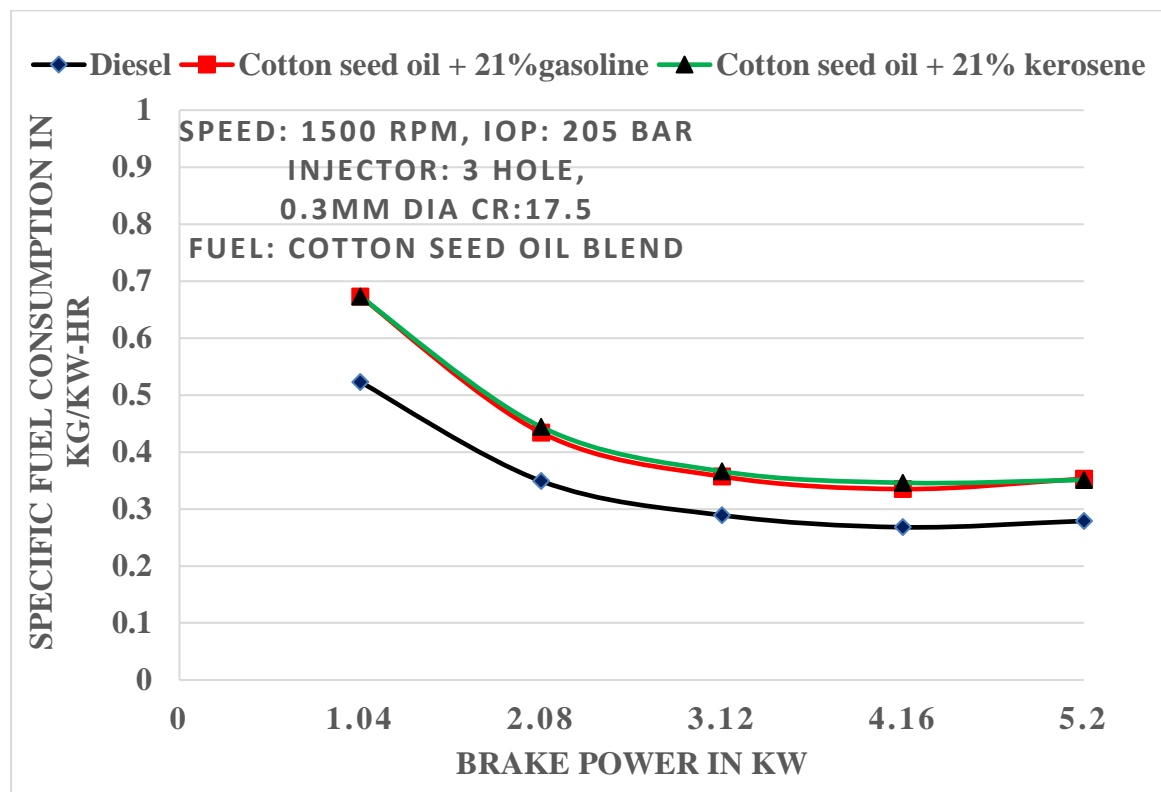


Fig 4.3 Effect of COB on SFC

4.2.4 SOOT DEPOSITION

It is the known fact for straight vegetable fueled oil engine the injector tip, piston head and cylinder head will have high deposition of soot and wax. These soot and wax deposition on piston, injector tip and on cylinder head may cause the parts sticky and also may clog the injector nozzle and valve passage either partially or fully. It was proposed oral inspection of soot deposition on cylinder head, piston and valves. The images show difference in soot deposition for blended fuel and diesel. On observing the injector tip, piston and cylinder head fueled by diesel and COB fuel. It is found that deposition on injector tip, piston and cylinder head is little high compared to the diesel fueled engine injector tip, piston and cylinder head as seen in figure 4.4 to 4.7. The deposition is considerably less when compared to SVO fueled engine parts. This may be due to

decrease in viscosity which makes the molecules lighter and increase in flowability in COB. In COB fueled engine the wax and soot deposition on injector tip, piston and cylinder head is less compared to SVO fueled engine and little high when compared to diesel fueled engine even though engine was running for ten long hours duration.

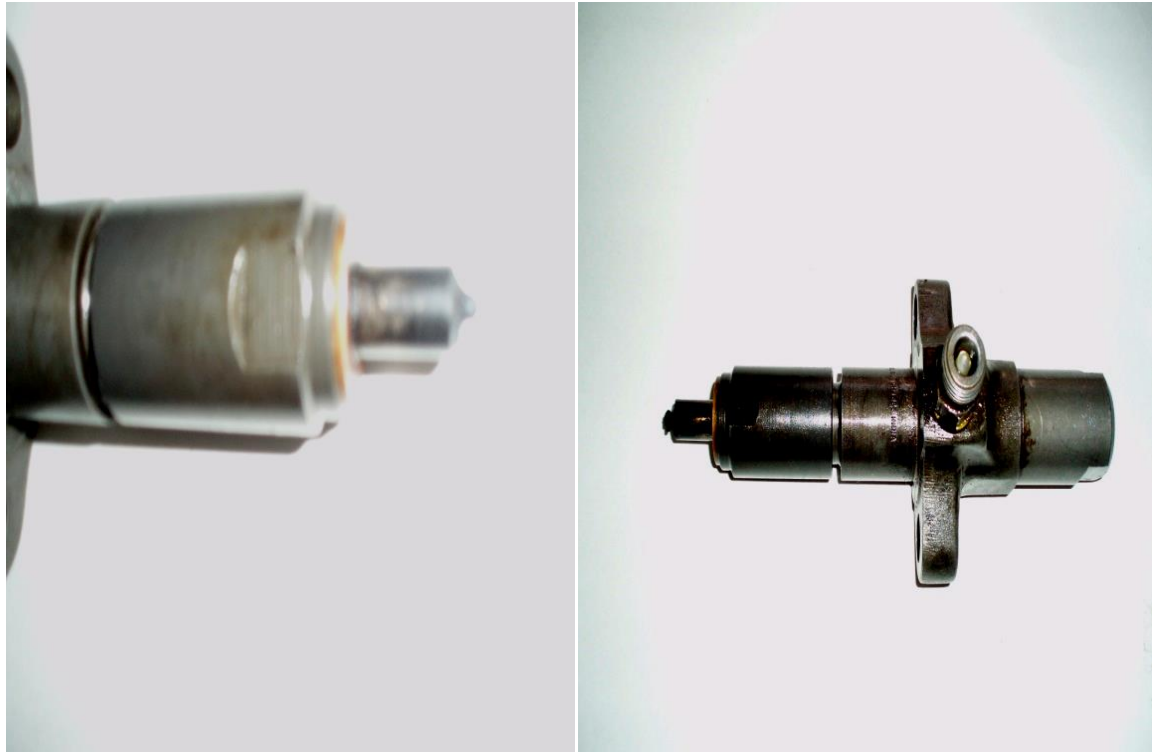


Figure 4.4 Injector tips of diesel-fueled engine and cotton seed oil blended fueled engine.



Figure 4.5 Piston top surface and ring sticking with diesel fueled engine and cotton seed blended oil fueled engine operation.



Figure 4.6 Carbon deposits on cylinder head with diesel fueled engine operation with new valves



Figure 4.7 Carbon deposits on cylinder head with cotton seed oil blended fueled engine operation

4.3 OVERALL RESULT ANALYSIS.

Brake thermal efficiency of both cotton seed oils blended with gasoline and kerosene is considerably less compared to standard diesel due to presence of oxygen molecules in the vegetable oil whereas diesel has chain of hydrocarbon molecules (COB with gasoline by 4.68% and COB with kerosene by 5%). BSFC of both blended fuels is more compared to that of diesel this may be due to comparatively low heat content. BTE of engine fueled with cotton seed oil blended with gasoline was slightly superior (by 0.32 % at 80% load) compared to cotton seed oil blended with kerosene this is due to relative volatility of fuels. Whereas BSFC for both blended fuels are almost same at 80% of load but more than diesel (by 5.8% at 80% load). The reasons could be that the blended vegetable oil being common the properties of kerosene and petrol had the bearing on the performance. Further when smoke emission is more for both blended fuels compared to diesel. The reason could be incomplete combustion. However, the engine performance was very close but well below that of the diesel fuel brake thermal efficiency. It was found that the soot deposition on piston, cylinder head and valve for blended vegetable oil operation found to be very minimal and was comparatively higher than diesel fuel operation.

CHAPTER 5

CONCLUSIONS

This work was aimed at studying performance, smoke emission and soot deposition of engine parts of a compression ignition engine operated on blended vegetable oil from Cotton seed, Jatropha seed and Castor seed oils. Experiments were conducted on CI engine at a constant speed of 1500 rev/min under variable load conditions with diesel. Next conduction of experiment was tried with non-edible blended Cotton seed oil with gasoline and kerosene. If straight vegetable oil is used as straight fuel then due to higher viscosities it is difficult to obtain the proper data. Hence, this oil was blended with gasoline and kerosene in different proportions out of these different proportion sample, based on the viscosity COB with 21% gasoline and COB with 21% kerosene is been selected as pilot fuel and then experiments were conducted at manufactured injection timing and injector opening pressure under variable load conditions.

Ethiopia grow cotton in abundance. Farmers can use locally available cotton seed to produce oil using portable oil expeller and mix with little quantity of gasoline which can be used as fuel works out to be inexpensive. Also as mentioned earlier farmers are residing in rural areas and accessibility to fossil fuel is from far of places the alternative is to keep stock it in huge quantity is economical bourdon and procuring in large quantity attracts more transportation cost. Hence usage of this renewable locally available vegetable blended oil will benefit farmers.

5.1 BLENDING COTTON SEED, JATROPHA AND CASTOR SEED OILS

- The quantity of gasoline and kerosene used for blending cotton seed, jathopha seed and castor seed oils need to be restricted to 21% by volume as beyond 21% the mixing of additive and vegetable oils will not yield homogeneous mixture.
- The Cotton seed oil yield from cotton seed is in the order of 18% by weight.
- The Jatropha seed oil yield from Jatropha seeds is in the order of 32% by weight.
- The Castor seed oil yield from Castor seeds is in the order of 24% by weight.
- The properties of Cotton seed, Jatropha seed and Castor seed oil blends with gasoline and kerosene found to be comparable to that of standard diesel.

5.2 EXPERIMENTS WITH COTTON SEED OIL BLENDS WITH GASOLINE AND KEROSENE AT ENGINE MANUFACTURER SPECIFIED INJECTION TIMING AND PRESSURE

It is possible to operate a CI engine with Cotton seed oil blends with gasoline and kerosene. The performance of the engine will be slightly poorer than diesel when operated at engine manufacturer specified injection timing, injection opening pressure. The satisfactory result is that the engine can be operated with COB without any staggaring. There is increase in in smoke emission compared to diesel operation. The most important outcome is that the soot deposition is very less compared to SVO operation and little high compared to diesel operation. The following conclusion presented for COB fuel operation.

- The decrease in brake thermal efficiency for COB with gasoline operation is 4.35% at 80% load compared to standard diesel operation.
- The decrease in brake thermal efficiency for COB with kerosene operation is 5% at 80% load compared to standard diesel operation.
- Increase in smoke emission for COB with gasoline operation is 18.2 % at 100% load compared to standard diesel operation.
- Increase in smoke emission for COB with kerosene operation is 22.72 % at 100% load compared to standard diesel operation.
- Among the selected blended fuel COB with gasoline is performing with better efficiency and reduced smoke emission compared to COB with kerosene fuel.

5.3 OVERALL CONCLUSIONS

The non-edible Cotton seed oil blend with gasoline and kerosene can be used as an alternative fuel in diesel engines. Use of Cotton seed oil as fuel require mixing of a small percentage of additives like gasoline and kerosene. The soot deposition and gum sticking on injector tip, piston head and cylinder head is less with operation of COB with gasoline compared to COB with kerosene.

5.4 SUGGESTIONS FOR FUTURE WORK

1. The present work can be extended to study the along with engine performance and emission characteristics using Cotton seed oil blends.
2. The present work can be extended to study the engine performance and emission characteristics using Cotton seed oil methyl ester(biodiesel) blends with gasoline and kerosene.
3. Further work can be taken up to study the effect of combustion chamber shapes on engine performance and emission characteristics using Cotton seed oil blends.
4. The results of the present work could be used for validating results of computer simulation models.

REFERENCES

1. Yang, L., Takase, M., Zhang, M., Zhao, T., Wu, X., 2014. Potential non-edible oilfeedstock for biodiesel production in Africa: A survey. *Renew. Sustain. Energy Rev.*
2. World Bank, 2008. *The growth report: Strategies for sustained growth and inclusive development.*
3. Oyelade, J.O., Idowu, D.O., Oniya, O.O., Ogunkunle, O., 2017. Optimization of biodiesel production from sandbax (*Hura crepitans* L.) seed oil using two different catalysts. *Energy Sources A Recover. Util. Environ. Eff.* 39 (12), 1242–1249
4. Ogunkunle, O., Oniya, O.O., Adebayo, A.O., 2017. Yield response of biodiesel production from heterogeneous and homogeneous catalysis of milk bush seed (*Thevetia peruviana*) oil. *Energy Policy Res.* 4 (1), 21–28.
5. Ogunkunle, O., Ahmed, N.A., 2019b. Response surface analysis for optimisation of reaction parameters of biodiesel production from alcoholysis of *Parinari polyandra* seed oil. *Int. J. Sustain. Energy* 38 (7), 630–648.
6. FACT. 2007. Position Paper on *Jatropha curcas* L. State of the art, small- and large-scale project development. *Fuels from Agriculture in Communal Technology* (available at <http://www.fact-fuels.org>).
7. Heller, J. 1996. *Physic nut. Jatropha curcas* L. Promoting the conservation and use of underutilised and neglected crops. 1. Gatersleben, Institute of Plant Genetics and Crop Plant Research and Rome, International Plant Genetic Resources Institute.
8. Achten, W.M.J., Verchot, L., Franken, Y.J., Mathijs, E., Singh, V.P., Aerts, R. & Muys, B. 2008. *Jatropha* bio-diesel production and use. *Biomass and Bioenergy*, 32: 1063–1084.
9. Gour, V. K. 2006. Production practices including post-harvest management of *Jatropha curcas*. In: Singh, B., Swaminathan, R., Ponraj, V. (eds). *Proceedings of the biodiesel conference toward energy independence – focus of Jatropha*, Hyderabad, India, June 9–10. New Delhi, Rashtrapati Bhawan, 2006: 223–251.
10. Jongschaap, R.E.E., Corré, W.J., Bindraban, P.S. & Brandenburg, W.A. 2007. *Claims and Facts on Jatropha curcas* L. Wageningen, Plant Research International.
11. Feto, A (2011). *Energy, greenhouse gas and economic assessment of biodiesel production from jatropha: the case of eastern and north eastern Ethiopia.* MSc thesis, Haramaya University, Ethiopia.
12. Wijnands, J, Biersteker, J and Hiel, R, (2007), (*Oild seeds business opportunities in Ethiopia,*” Ministry of Agriculture, nature and food quality, the Netherlands.
13. Sahoo P.K., Das L.M., Babu M.K.G., Arora P., Singh V.P., Kumar N.R., Varyani T.S., Comparative evaluation of performance and emission characteristics of *Jatropha*, *Karanja* and *Polanga* based biodiesel as fuel in a tractor engine, *Fuel*, Vol. 88, 2009, pp 1698 – 1707.

14. Haldar S. K., Ghosh B.B., Nag A., Studies on the comparison of performance and emission characteristics of a diesel engine using three degummed Non-edible Vegetable oils, *Biomass and Bioenergy*, Vol. 33, 2009, pp. 1013-1018.
15. Hanny Johanes Berchmans, Shizuko Hirata. Biodiesel production from crude *Jatropha curcas* L. seed oil with a high content of free fatty acids. *Bioresource Technology* 2008; 99:1716–1721.
16. Seema Raj, Meena Bhandari. Comparison of Methods of Production of Biodiesel from *Jatropha Curcas*, November 2017, DOI: 10.5958/0976-4763.2017.00009.5
17. A A.S.Silitongaab, A.E.Atabania, T.M.I.Mahliaad, H.H.Masjuki, Irfan Anjum Badruddina, S.Mekhilef. A review on prospect of *Jatropha curcas* for biodiesel in Indonesia *Renewable and Sustainable Energy Reviews*, Volume 15, Issue 8, October 2011, Pages 3733-3756
18. Xin Deng a , Zhen Fang a,* , Yun-hu Liu a , Chang-Liu Yu Production of biodiesel from *Jatropha* oil catalyzed by nanosized solid basic Energy xxx (2011) 1-8
19. H.P.S. Abdul Khalil, N.A. Sri Aprilia, A.H. Bhat, M. Jawaid, M.T. Paridah, D. Rudi. A *Jatropha* biomass as renewable materials for biocomposites and its applications. *Renewable and Sustainable Energy Reviews* 22 (2013) 667–685
20. Augustus GDPS, Jayabalan M, Seiler GJ. Evaluation and bioinduction of energy components of *Jatropha curcas*. *Biomass and Bioenergy* 2002;23: 161–4
21. A Karthikeyan, J Jayaprabakar. Richard Dude Williams. Experimental Investigations on Diesel engine using Methyl esters of *Jatropha* oil and fish oil. IOP Conference Series: Materials Science and Engineering, Volu
22. I.M. Rizwanul Fattah, H.H. Masjuki, M.A. Kalam, M.A. Wakil, H.K. Rashedul, M.J. Abedin. Performance and emission characteristics of a CI engine fueled with *Cocos nucifera* and *Jatropha curcas* B20 blends accompanying antioxidants. *Industrial Crops and Products* 57 (2014) 132–140.
23. Bhupendra Singh Chauhan, Naveenkumar, Haeng Muk Cho. A study on the performance and emission of a Diesel engine fuelled with *Jatropha* biodiesel oil and its blends. 2012. *Energy* 56(1). DOI: 10.1016/j.energy.2011.10.043
24. M. Moniruzzaman, Zahira Yaakob, M. Shahinuzzaman, Rahima Khatun and A.K.M. Aminul Islam, 2017, “*Jatropha* Biofuel Industry: The Challenges”, *Frontiers in Bioenergy and Biofuels*, INTECH Open Science, 224-256.

25. Miftah Fekadu, Sisay Feleke , Tsegaye Bekele, 2019, “Selection of seed oil biodiesel producing tree species, emission reduction and land suitability,” *AgricEngInt: CIGR Journal*, 21 (4), 132-143.
26. Duple Sinha, S.Murugavelh, Biodiesel production from waste cotton seed oil using low cost catalyst: Engine performance and emission characteristics, *Perspectives in Science*, Volume 8, September 2016, Pages 237-240
27. Rashid U, Anwar F and Knothe G Biodiesel from Milo (*Thespesiapopulnea L.*) seed oil 2011 *Biomass. Bioenerg* 35 4034-39. 21.
28. Md Nurun Nabi, Md Mostafizur Rahman, Shamim Akhter, Biodiesel From Cotton Seed Oil and its Effect on Engine Performance and Exhaust Emissions, *Applied Thermal Engineering* 29, (11-12), 2009, pp 2265-2270 DOI: 10.1016/j.applthermaleng.2008.11.009.
29. Basavaraj M.Shrigiri, Omprakash D.Hebbal, K. Hemachandra Reddy, Performance, emission and combustion characteristics of a semi-adiabatic diesel engine using cotton seed and neem kernel oil methyl esters, *Alexandria Engineering Journal*, Volume 55, Issue 1, March 2016, Pages 699-706
30. Y. V. H. Rao, R. S. Voleti,A. V. S. Raju &P. N. Reddy, The effect of cottonseed oil methyl ester on the performance and exhaust emissions of a diesel engine, | 2011 Pages 203-210, <https://doi.org/10.1080/01430750.2010.9675813>
31. G Bhargavi, P Nageswara Rao, S Renganathan Production of Biodiesel from *Thespesiapopulnea* seed oil through rapid in situ transesterification - an optimization study and assay of fuel properties. *IOP Conf. Series: Materials Science and Engineering* 330 (2018) 012046 doi:10.1088/1757-899X/330/1/012046
32. Hüseyin Serdar Yücesu and Cumali İlkiliç, Effect of Cotton Seed Oil Methyl Ester on the Performance and Exhaust Emission of a Diesel Engine, Pages 389-398 | Published online: 19 Aug 2006, <https://doi.org/10.1080/009083190927877>
33. Dominic Okechukwu Onukwuli, Lovet Nwanneka Emembolu, Callistus NonsoUde, Sandra OgechukwuAliozo, Mathew Chukwudi Menkiti, Optimization of biodiesel production from refined cotton seed oil and its characterization. *Egyptian Journal of Petroleum*, Volume 26, Issue 1, March 2017, Pages 103-110

34. Chen He, Peng Baoxiang , Wang Dezheng , Wang Jinfu. Biodiesel production by the transesterification of cottonseed oil by solid acid catalysts, *Frontiers of Chemical Engineering in China*, February 2007, Volume 1, Issue 1, pp 11–15.
35. K Sundar, R Udayakumar, C.Periasamy, Shashank Khurana, 2019“Cotton Seed Oil and Rice Brand Oil as a Source of Biodiesel” IOP Conference Serices: *Journal of Physics: Conf, Series*, 1276, 012086, doi:10.1088/1742-6596/1276/1/012086.
36. Parvaneh Zareh, Ali Asghar Zare, Barat Ghobadian. Comparative assessment of performance and emission characteristics of castor, coconut and waste cooking-based biodiesel as fuel in a diesel engine, *Energy*, Volume 139, 15 November 2017, Pages 883-894.
37. T. Prakash, V. Edwin Geo, Leenus Jesu Martin, B. Nagalingam, Effect of ternary blends of bio-ethanol, diesel and castor oil on performance, emission and combustion in a CI engine, *Renewable Energy*, Volume 122, July 2018, Pages 301-309
38. Mithun Das, Mouktik Sarkar, Amitava Datta, Apurba Kumar Santra, An experimental study on the combustion, performance and emission characteristics of a diesel engine fuelled with diesel-castor oil biodiesel blends, *Renewable Energy*, Volume 119, April 2018, Pages 174-184
39. Akash Deep, Sarbjot Singh Sandhu, Subhash Chander, Experimental investigations on the influence of fuel injection timing and pressure on single cylinder C.I.engine fueled with 20% blend of castor biodiesel in diesel, *Fuel*, Volume 210, 15 December 2017, Pages 15-22
40. N. L. Panwar, Hemant Y. Shrirame, N. S. Rathore, Sudhakar Jindal, A. K. Kurchania, Performance evaluation of a diesel engine fueled with methyl ester of castor seed oil, *Applied Thermal Engineering*, Volume 30, Issues 2–3, February 2010, Pages 245-249
41. Syed Shahbaz Anjum, Om Prakash, Impact of Kerosene Oil Blend with Diesel Fuel on Engine Performance: An Experimental Investigation. *International Journal of Engineering and Technology (IJET)*, Vol 9, No 3S, 2017, ISSN (Online): 0975-4024, pp 16-127
42. Philippe Dagaut, Michel Cathonne the ignition, oxidation, and combustion of kerosene: A review of experimental and kinetic modeling. *Progress in Energy and Combustion Science* 32 (2006) 48–92

43. Wenming Yanga Kun, Lin Taya Kah Wai Konga, Impact of Various Factors on the Performance and Emissions of Diesel Engine Fueled by Kerosene and Its Blend with Diesel, *Energy Procedia*, Volume 142, December 2017, Pages 1564-1569
44. H. Bayindir, The Effects of Cottonseed Oil–Kerosene Blends on a Diesel Engine Performance and Exhaust Emissions, *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, Volume 32, 2010 - Issue 10, 2010, Pages 901-908
45. Naseer Salman Kadhim. Study the effect of blending kerosene with diesel fuel on the performance and emissions of diesel engine. *International journal of engineering sciences & research Technology*, 2015, ISSN: 2277-9655
46. Bilal A. Akash. Combustion and Emission Investigation of Diesel Fuel and Kerosene Blends. *Research Journal of Applied Sciences, Engineering and Technology* 10(6): 618-622, 2015, ISSN: 2040-7459; e-ISSN: 2040-7467
47. Rubiat Mustak and Tanjim Ahmed, (2018):” Investigating the Effect of Blending Kerosene and Palm Oil with Diesel Fuel” *International Journal of Scientific & Engineering Research* Volume 9, Issue 2, February-2018, 1271 ISSN 2229-5518.
48. Hasan Bayindir, Performance Evaluation of a Diesel Engine Fueled with Cotton Oil-Kerosene Blends, **e-Journal of New World Sciences Academy**, 2007, Volume: 2, Number: 1, Article Number: A0016. Sahoo P.K., Das L.M., Babu M.K.G., Arora P., Singh V.P., Kumar N.R., Varyani T.S., Comparative evaluation of performance and emission characteristics of Jatropha, Karanja and Polanga based biodiesel as fuel in a tractor engine, *Fuel*, Vol. 88, 2009, pp 1698 – 1707.
49. Haldar S. K., Ghosh B.B., Nag A., Studies on the comparison of performance and emission characteristics of a diesel engine using three degummed Non-edible Vegetable oils, *Biomass and Bioenergy*, Vol. 33, 2009, pp. 1013-1018.
- 50. Naseer Salman Kadhim**, Study the Effect of Blending Kerosene with Diesel Fuel on the Performance and Emissions of Diesel Engine, **International Journal of Engineering Sciences & Research Technology**, 4(8): August, 2015, ISSN: 2277-9655.
- 51. A. K. Azad, S. M. Ameer Uddin, M. M. Alam**, Experimental study of DI diesel engine performance using biodiesel blends with kerosene, **International Journal of Energy and Environment**, Volume 4, Issue 2, 2013 pp. 265-278.

52. Raheman, H. and Phadatare A.G, (2004): “Diesel engine emissions and performance from blends of karanja methyl ester and diesel”. *Biomass and Bioenergy*, 27, 393-397.
53. Atabani, A.E., Silitonga A.S., Ong H.C., Mahli T.M.I., Masjuki H.H., Badruddin I. A., Fayaz H., (2013): “Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emission production”, *Renewable and Sustainable Energy Reviews*, 18, 211–245.

APPENDICES

APPENDIX 1

Specifications of the Engine

Make and Model	Kirloskar, TV1
No. of Cylinders	One
Orientation	Vertical
Cycle	4 Stroke
Ignition System	Compression Ignition
Bore X Stroke	87.5mm X 110mm
Displacement Volume	660 cc
Compression Ration	17.5 : 1
Arrangement of valves	Overhead
Combustion Chamber	Open Chamber (Direct Injection)
Rated Power	5.2 kW (7 HP) @ 1500 rpm
Cooling Medium	Water cooled

APPENDIX 2

Specifications of the Dynamometer

Make	SAG, Pune
Model	AG - 10
Type	Eddy current
Power	7.5 kW
Volts	Max 75 V (DC)
Amps	2 A (Max)
Speed	3000 rpm

APPENDIX 3

Specifications of Smoke Meter

Type	HARTRIDGE SMOKEMETER-4
Object of Measurement	Smoke
Measuring range opacity	0 – 100 %
Accuracy	+ / -2 % relative
Resolution	0.1 %
Smoke length	0.43 m
Ambient Temperature Range	-5° C to + 45° C
Warm up time	10 min. (self-controlled) at 20 ⁰ C
Speed of Response Time	Within 15 sec. for 90% response
Sampling	Directly sampled from tail pipe
Power Supply	100 to 240 V AC / 50HZ 10 – 16 V DC @ 15 amps
Size	100 mm x 210 mm x 50 mm.

CERTIFICATE

Certificate from KLE technological University, Hubli, India the laboratory in which experimentations are carried out.



Earlier known as
B. V. B. College of Engineering & Technology

To whomsoever concerned,

Date: 08-06-2020

Dr. Suresh G., Associate professor, mechanical engineering department, Adama Science and Technology University, ADAMA, Ethiopia has been given permission to conduct experiments on a single cylinder diesel engine coupled with eddy current dynamometer from 16th July 2018 to 27th July 2018 in the institution With reference to his request letter dated 9th July 2018.

--

Dr. N.R. Banapurmath
Professor and Head (Centre for Material Science)
Professor, School of Mechanical Engineering
B.V.B. College of Engineering and Technology
KLE Technological University
Vidyanagar, Hubli-580031. Karnataka State,
INDIA

HEAD
Center for Material Science
K.L.E. Technological University
HUBBALLI-580 031.