A Comparative Study of Diesel Engine Performance and Emission Characteristics of Biodiesel Blends with Diesel

S. Nandha Kumar, V. Boopathiraja, A. Charles Frank

***Abstract*— This paper is aimed at study of the performance and emission characteristics of direct injection diesel engine fueled with linseed oil and cottonseed oil mixing biodiesel blends with diesel fuel. The comparison was done with base fuel as diesel and cottonseed oil and linseed oil biodiesel blends. The experiment was conducted with various blends of biodiesel at different engine loads. It was found that BMEP, Indicated thermal Efficiency, Brake thermal efficiency and Specific fuel consumption is slightly maintained at base fuel performance. The emission of Carbon dioxide (CO_2), Unburnt hydrocarbons(HC), Oxides of nitrogen(NO_x) and exhaust gas temperature (EGT) were less compare with base fuel but smoke density and carbon monoxide (CO) were slightly increased compare with base fuel.**

***Index Terms*— Biodiesel, linseed oil, cottonseed oil, transestrification, B05, B10, B15, performance and emission parameters.**

I. INTRODUCTION

Modern civilization is much dependent on fossil energy. Energy obtained from fossil resources is much higher than any other resources. Majority of the world energy needs are supplied thorough petrochemical resources, coal, oil and natural gas. The consumption of fossil fuel is on increasing from year to year. The petroleum based fuels are also highly contributing to environment pollution. Biodiesel is the suitable option for transportation vehicles. Vegetable oils, due to the agricultural origin, are able to reduce the net CO2, HC and NOX emission.

With greater environmental concerns and long term sustainability point of view, it becomes necessary to develop alternative fuels with properties comparable to petroleum based fuels. It is important to long term plan for alternative energy sources in a balanced manner by making optimal use of available land and manpower resources.

It is being more important to study the feasibility of substitution of diesel with an alternative fuel, which can be produced locally on a substantial scale for commercial utilization. Vegetable oils are considered as good alternatives to diesel as their properties are close to diesel. But direct utilization of vegetable oils in internal combustion engine causes some problems due to the their high viscosity compared with conventional diesel fuel. Various techniques and methods are used to solve the problems resulting from high viscosity. Transesterification of vegetable oils is the most commonly adopted technique, which helps converting vegetable oils into biodiesel fuel. Our work mainly concerning in the area of testing the performance of the diesel engine when running with a biodiesel.

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1.1. Linseed oil

Linseed (Linum usitatissimum) is a naturally growing crop requiring less water for its life cycle. It is available in most of the regions of the world. It is also known by various names like Chih-ma, Lint Bells, Winterlien, etc., there are many unsaturated fats as well as mucilage in the linseed. The linseed oil is abundantly available oil and renewable in nature.

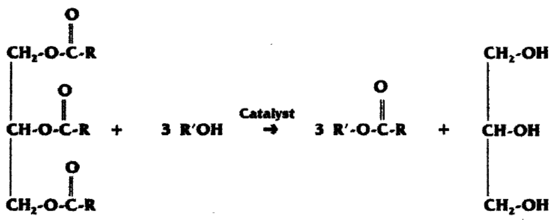
1.2. Cottonseed oil

Cottonseed oil is a cottonseed oil extracted from the seeds of cotton plants of various species, mainly Gossypium hirsutum and Gossypium herbaceum, that are grown for cotton fiber, animal feed, and oil. Cottonseed has a similar structure to other oilseeds such as sunflower seed, having an oil-bearing kernel surrounded by a hard outer hull; in processing, the oil is extracted from the kernel. Cottonseed oil is used for salad oil, mayonnaise,salad dressing, and similar products because of its flavor stability.

II. TRANSESTERIFICATION REACTION

The vegetable oils are extracted from crude oil. There crude oil ususlly contain free fatty acids (FFA), water, sterols, phospholipids and impurities. Its can causes numerous problems in diesel engine. It also increased viscosity, low volatility and poor cold flow properties. They lead to severe engine deposits, injector coking, piston ring sticking etc.,. Biodiesel may be produced by following four ways: Pyrolysis, Micro emulsification, Dilution and Transestrification.

In this work transestrification process is used to prepare biodiesel from linseed and cottonseed oil. It is the process of using an alcohol (eg. Methanol, ethanol and butanol), in the presence of catalyst, such a sodium hydroxide or potassium hydroxide, to break the molecule of raw renewable oil chemically into methyl or ethyl esters of the renewable oil, with glycerol as the byproduct. Transestrification reaction for vegetable oil:



Transestrification also called as alcoholysis is the displacement of alcohol from an ester by another alcohol in a process similarly to hydrolysis except that an alcohol is used instead of water. This have been widely used to reduce the viscosity of the triglycerides.

2.1.Laboratory Procedures for the production of linseed and cottonseed oil

First oil is produced by using the press machine squeezing the linseed and cottonseed. Normally there are different kinds of production of oil from their seeds. The oil produced by the mechanism has some residues remained with it, and then it requires some filtration using filter. Therefore, the oil has been filtered.

2.2. Transestrification process

The raw oil is heated upto 135^{o}C then a mixture of methanol (100ml) and potassium hydroxide (3.5gm) is added to it and stirring for 20minutes. the product was allowed to settled for 24hrs to produce two distinct liquid phases: crude ester phase at the top and glycerol phase at the bottom. Glycerol was separated using separating funnel.

2.3.Production of Biodiesel

The crude ester was separated from glycerol using separating funnel. Crude methyl ester containing excess alcohol, soap and glycerol was washed with water two times the amount of crude biodiesel, so that the molecules will move freely and separate easily and quickly. It was purified by washing with distilled water to remove all the residual by-products. The crude biodiesel and water mixture was shaken thoroughly for 1 min and placed on a table to allow separation of biodiesel and water layers. The washing process was repeated for several times until the washed water became clear. The washed biodiesel was heated at 110 ºC for 3-4 mins, so that remaining water will be evaporated. Then pure biodiesel is prepared.

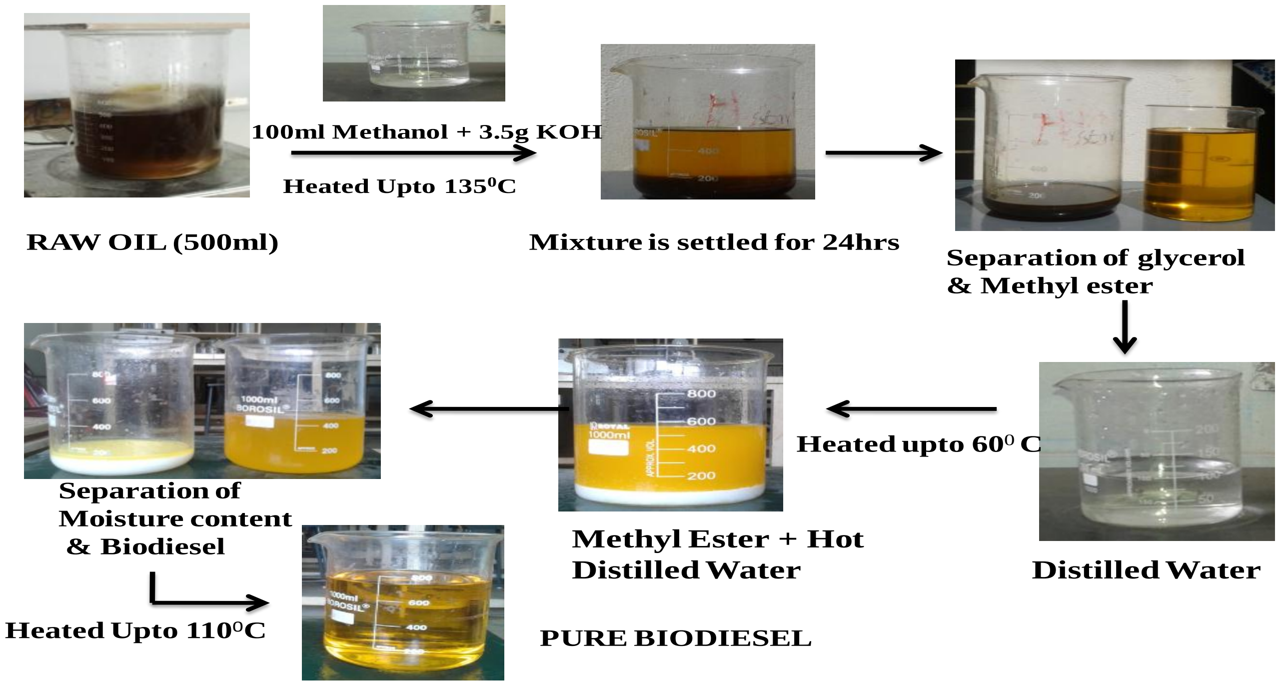


Figure 1: Process for preparing biodiesel

Table 1: Properties of biodiesel blends, linseed andcottonseed biodiesel and diesel.

S.NO	Properties	Units	B05	B10	B15	Diesel	Linseed Biofuel	Cottonseed Biofuel
1	Density	Kg/m^3	825	830	835	823	840	910
2	Specific Gravity	_	0.825	0.83	0.835	0.823	0.84	0.91
3	Flash Point	^{0}C	45	47	49	43	172	165
4	Fire Point	^{0}C	53	56	60	45	187	180
5	Calorific Value	KJ/kg	42700	41200	40300	44800	35225	38000
6	FreeFatty Acid	%	0.07	0.084	0.107	0.11	0.085	0.05
7	Viscosity	CST	3.12	3.29	3.68	2.97	22.22	55.61

III. EXPERIMENTAL SETUP AND PROCEDURE

A naturally aspirated single cylinder direct injection diesel engine test rig was used for experimental study. The specification of engine and instrumentation are shown in table 2. Initially the engine was run at no load condition and at rated speed (1500 ± 10rpm). Then tests were performed at varying loads, i.e., 20,40,60,80,100%; with different blends of linseed and cottonseed biodiesel with diesel (B05,B10 and B15). After initially warm-up of engine for more than 30min, when the engine exhaust and other temperatures were stabilized, the engine was run at different loads and the reading were taken after study temperatures were reached. The performance of the engine at different loads and settings was evaluated in terms of brake power(BP), brake thermal efficiency(B_{th}), specific fuel consumption(SFC), indicated thermal efficiency(I_{th}), indicated power(IP), mechanical efficiency(η_{mech}), indicated mean effective pressure(IMEP), and emission of carbon monoxide(CO), carbon-di-oxide(CO_2), un-burnt hydrocarbons(HC), oxides of nitrogen(NO_X), smoke density and exhaust gas temperature(EGT).

Table 2: Test Engine Specification

Items	Engine Data
Model	Kirloskar TV1
Engine Type	Single Cylinder, 4-stroke
Cylinder Dia	87.5mm
Stroke Length	110mm
Nominal Speed	1500rpm
Nominal Power	5.2KW
Compression Ratio	17.5:1
Loading Device	Eddy current Dynamometer

IV. RESULTS AND DISCUSSION

4.1.Performance Characteristics

Various engine performance characteristics such as B_{the}, SFC and Mechanical Efficiency were analyzed for all biodiesel blends and diesel at different engine loads.(20,40,60,80,100%).

4.1.1.Specific Fuel Consumption

Figure 2 shows the specific fuel consumption of various biodiesel blends and diesel. It is observed that SFC higher for all biodiesel blends than diesel under various loading condition.SFC is slightly increased for all blends when compared to diesel. This is due to high viscosity,density, lower heating value of biodiesel.A more relevant parameter to compare engine parameter is specific fuel consumption.

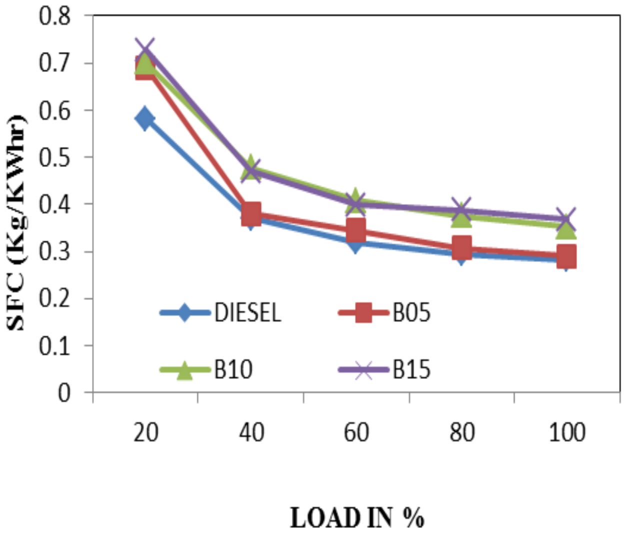


Figure 2: Load in % vs SFC

4.1.2.Mechanical Efficiency

Figure 3 shows the comparison of mechanical efficiency for various biodiesel blends with diesel. This is the rating that shows how much of the power developed by the expansion of the gases in the cylinder is actually delivered as useful power. The factor which has the greatest effect on mechanical efficiency is friction with in the engine. The friction power of biodiesel blends has been increased with diesel. Thus the mechanical efficiency of the engine has been slightly decreased when compared to the diesel.

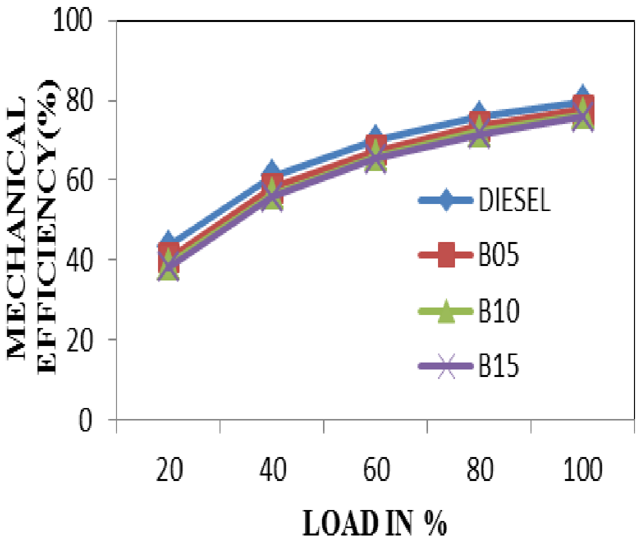


Figure 3: Load in % vs Mechanical Efficiency

4.1.3. Brake Thermal Efficiency

Brake thermal efficiency is the ratio of brake power to the energy released during the combustion process. Figure 4 shows the variation of the brake thermal efficiency of biodiesel blends with respect to diesel. It was found that brake thermal efficiency of biodiesel blends is slightly lower than the diesel. This is due to biodiesel blends lower heating value, higher density and increased viscosity which leads to poor atomization and fuel vapourization.

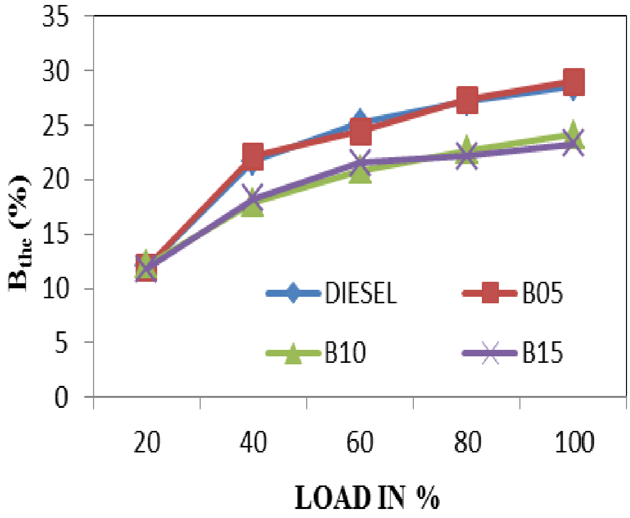


Figure 4: Load in % vs Brake thermal Efficiency

4.2. Emission Characteristics

Various engine emission characteristics such as smoke density, CO, CO2, unburnt HC, NOx were analyzed for all biodiesel blends and compared with diesel fuel.

4.2.1.Smoke Density

The smoke content of all biodiesel blends and diesel is shown in figure 5. From the figure it can be seen that this smoke content of the biodiesel blends are 7%, 15% and 29% higher for B05, B10, B15 when compared to the diesel fuel at full load condition. This is due to high viscosity of biodiesel, which results in poor atomization.

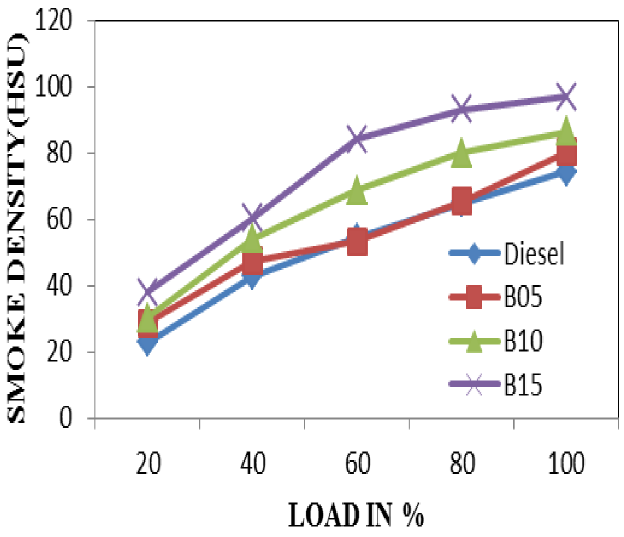


Figure 5: Load in % vs Smoke Density

4.2.2. Unburnt Hydrocarbons

The unburnt hydrocarbons emissions for all biodiesel blends and diesel are shown in figure 6. A 6.4%, 13.6%, 26% of unburnt hydrocarbons has been lower than the diesel at full load condition. This is due to better combustion that means the biodiesel involves high oxygen content, which leads to more complete combustion.

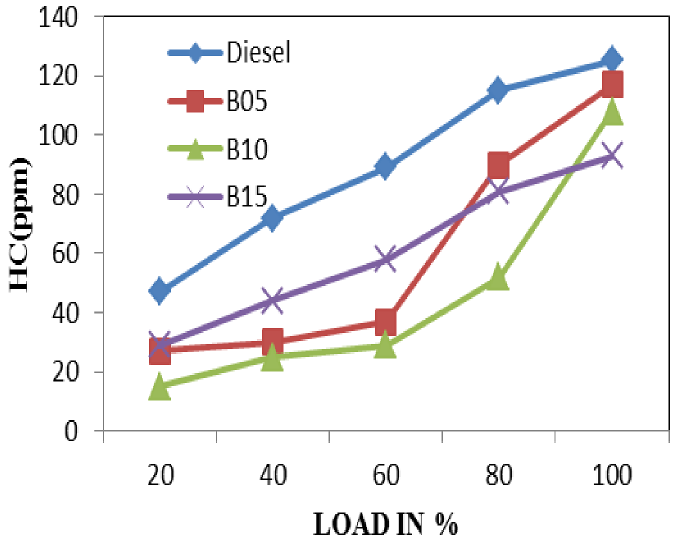


Figure 6: Load in % vs Unburnt Hydrocarbons

4.2.3.Carbon Monoxide

Figure 7 gives the comparison of the CO emission of biodiesel blends with diesel. CO is one of the intermediate compounds formed during the intermediate combustion stage of hydrocarbon fuels. CO formation depends on the air fuel equivalence ratio, fuel type, combustion chamber design, starting of injection timing, injection pressure and speed. Experimental results reveal that CO concentration of biodiesel blends is 105%, 70%, 45% higher for B05, B10, B15 when compared to diesel fuel. This is due to when there is not enough oxygen to convert all carbon to CO_2 so CO has produced.

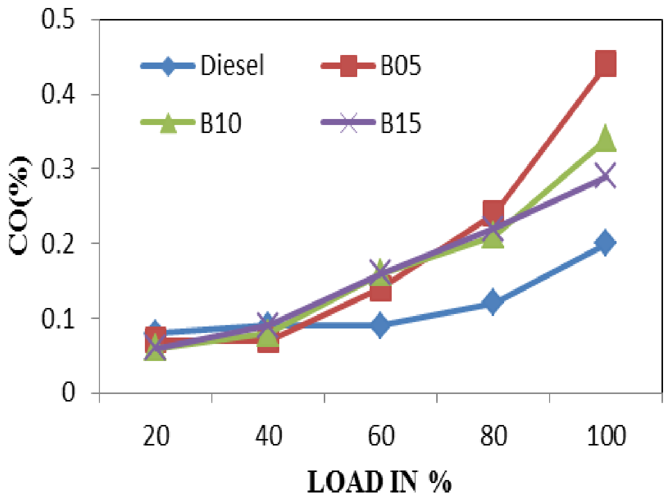


Figure 7: Load in % vs Carbon monoxide

4.2.4.Carbon Dioxide

Figure 8 shows the carbon dioxide emission at constant speed of the engine. The carbon dioxide emission for all biodiesel blends is 12%, 15%, 15.5% less as compared to diesel at full load. Biodiesel contains lower carbon content as compared to diesel and hence the CO_2 emission is comparatively lower.

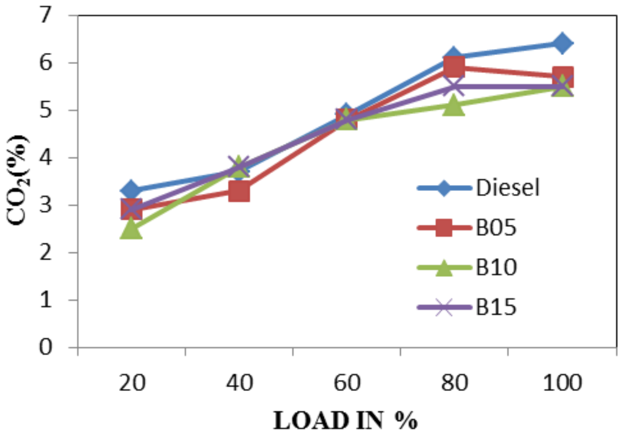


Figure 8: Load in % vs Carbon dioxide

4.2.5.Oxides Of Nitrogen

The variations of oxides of nitrogen (NOx) concentration with load for biodiesel blends and diesel is shown in figure 9. NOx formation of all biodiesel blends is lower than the diesel fuel, content of B05, B10, B15 is 4%, 27% and 36% less than conventional diesel fuel under full load condition. This is due to lower temperature occurs in the combustion and presence of oxygen with biodiesel causes lower NOx emission.

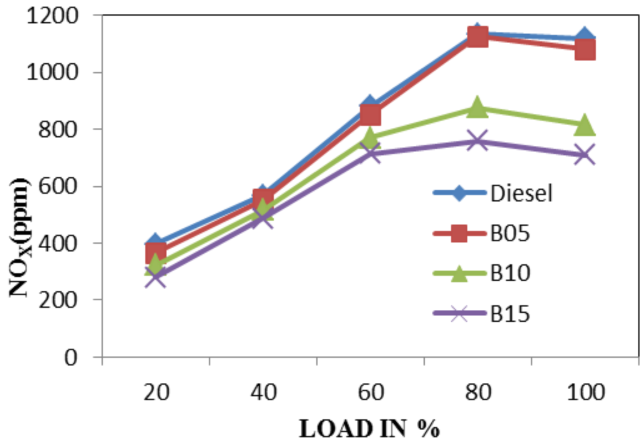


Figure 9: Load in % Vs Oxides of Nitrogen

V. CONCLUSION

In present investigation the performance and emission characteristics of direct injection compression ignition engine fueled with biodiesel blends have been discussed and compared with diesel fuel. The following conclusion may be drawn from the experiment.

1. Biodiesel can be produced from linseed oil and cottonseed oil using transestrification reaction.
2. It is possible to run diesel engine with biodiesel blends without any engine modification.
3. SFC for biodiesel blends has been higher than the diesel, because of lower heating value of biodiesel.
4. Compare to diesel fuel, a little amount of power loss occurs in biodiesel blends due to higher viscosity and density.
5. It also observed that there is the significant reduction in CO_2, unburnt HC, NOx emissions for biodiesel blends compare with diesel fuel. However, CO and Smoke emission of biodiesel blends is marginally higher than the diesel fuel.

It can be concluded that B15 biodiesel blend could replace the diesel in order to help in controlling air pollution and reduce dependency of fossil fuel resources to some extent without sacrificing engine performance.

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