EFFECT OF ENGINE PERFORMANCE AND EMISSION CHARACTERISTICS OF NON-EDIBLE OILS

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ABSTRACT

Due to the energy crisis caused by the depletion of resources and increased environmental problems combined with the great need for edible oil as food and the reduction in biodiesel production cost, inedible oils are preferred as an alternative fuel for diesel engine. Among different non-edible vegetable oils which can be used as alternate fuels, four vegetable oils, i.e. Jatropha (Jatropha curcas), Pongamia (Pongamia pinnata), Mahua (Madhuca indica), Neem (Azadirachta indica) oils were selected for analysis in this paper. Since there is a variation in the physical properties of these four alternate fuels and their biodiesels, a comparative analysis is done for methyl esters of different oils in blends with diesel of different proportions. It is clear from this study that biodiesel generally causes an increase in NOx emission and a decrease in HC, CO and smoke emissions compared to diesel. It is also found that a diesel engine would run successfully on a blend of 20% biodiesel and 80% diesel fuel without damage to engine parts. Also methyl ester from Jatropha oil, with properties close to diesel shows better performance and emission characteristics, followed by esters of Pongamia, Neem and Mahua oils.

Keywords: Biodiesel, Jatropha ,Pongamia, NeemandMahua.

INTRODUCTION

It is known that the remaining global oil resources appear to be sufficient to meet demand up to 2030 as projected in the 2006– 2007 world energy outlook by the International Energy Agency (Kjarstad et al 2009). There is, therefore, a demand to develop alternative fuels motivated by the reduction of the dependency on fossil fuel due to the limited resources. In this respect biodiesel have been proposed as alternate solution for increasing of energy demand and environmental awareness. Vegetable oil is not a new fuel for CI engine hundred years ago Mr. Rudolf Diesel tested vegetable oil for his engine. (Chen Hu et al 2010). Diesel demonstrated his engine at the Paris Exposition of 1900 using peanut oil as fuel. In 1911 he stated “The Diesel engine can be fed with vegetable oils and would help considerably in the development of Agriculture of the countries which use it”. In 1912, Mr. Rudolf Diesel said, “The use of vegetable of oils for engine fuels may seem insignificant today. But such oils may become in course of time as important as petroleum and the coal tar products of the present time” (Babu et al 2003). With the advantages of the cheap petroleum, appropriate crude oil fractions were refined to be used as fuel and Diesel engine were evolved together. In the 1930s and 1940s vegetable oils used as diesel fuels from time to time, but usually only in emergency situations. Recently, because of rise in crude oil prices, limited resources of fossil fuel, environmental concerns, there has been a renewed focus on vegetable oils to make bio diesel fuels (Hak-Joo Kim et al 2004).

It is well known that biodiesel is not toxic, contains no aromatics, has higher biodegradability than diesel, is less polluting to water and soil and does not contain sulphur (Paramanik 2003). Bio-diesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a bio-diesel blend or can be used in its pure form. Just like petroleum diesel, bio-diesel operates in compression ignition engine; which essentially require very little or no engine modifications because bio-diesel has properties similar to petroleum diesel fuels. It can be stored just like the petroleum diesel fuel and hence does not require separate infrastructure. The use of bio-diesel in conventional diesel engines results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particulate matters. Bio-diesel is considered clean fuel since it has almost no sulphur, no aromatics and has about 10 % built- in oxygen, which helps it to burn fully. Its higher cetane number improves the ignition quality even when blended in the petroleum diesel (Advani 2003).

According to the Ethiopian Ministry of Mines and Natural Gas, the country has found the largest deposit of Natural gas in its south-west (in the Ogaden Basin) and will begin to produce 4.7 Trillion Cubic Meters over the next 2 years. This huge reserve, besides its use as a household energy supply, it will be a great promises for future application as a substitution of Petrol fuel.

Due to its green economy policy, Ethiopia is forcing to look transport fuel sources other than Petroleum product fuels.

Since the edible oil demand for household consumption is higher than its domestic production, Ethiopia is not in a position to use edible oil for automotive application. But

different nations across the world are looking for different vegetable oils as an alternative for diesel fuel; soybean oil in the USA, rapeseed and sunflower oils in Europe, palm oil in South East Asia and coconut oil in Philippines are being considered as substitutes for diesel fuel.

Being a tropical country, Ethiopia is a treasure land for forest resources having a wide range of trees, which yield a significant quantity of oilseeds.

In Ethiopia according to “The Biofuel Development & Utilization Strategy” the biodiesel that is to be produced from jatropha curcas, caster bean, and palm tree aimed to ensure use of biodiesel for transportation, a high level of blend, substitute biodiesel for domestic cooking and lighting fuel, etc (FDRE Ministry of Mines and Energy, 2007),

METHODS AND MATERIALS

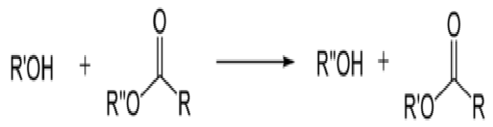
Transesterification of vegetable oils

There are three basic routes for ester production from oils and fats. They are as follows.

1. Base catalyzed trans-esterification of the oil with alcohol.
2. Direct acid catalyzed esterification of the oil with methanol.
3. Conversion of the oil to fatty acid and then to alkyl esters with acid catalysis.

The majority of trans-esterification is done by the first method.

Transesterification is the exchange of an alkyl group of an alcohol with the alkyl group of an ester.



Biodiesel is obtained by reacting vegetable oils with alcohols to produce fatty acid alkyl esters with sodium or potassium hydroxide as catalyst. Methanol is most commonly used for the purpose since it is the cheapest alcohol available. Ethanol and higher alcohols such as isopropanol, butanoletc can also be used for the esterification. Using higher molecular weight alcohols improves the cold flow properties of biodiesel but reduces the efficiency of transesterification process in fig.A.

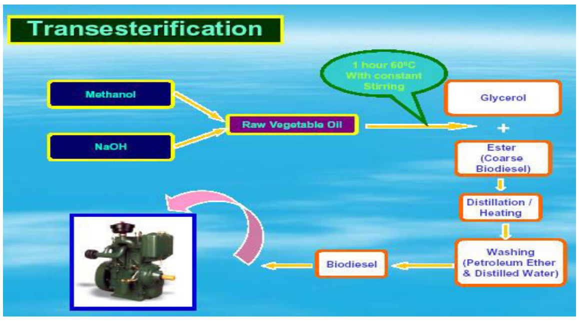


Fig.A - Test setup for transesterification process

The steps in transesterification are as follows

1. First dissolve the sodium hydroxide into the methanol. Shake or swirl until all the sodium hydroxide has dissolved.

2. This may take 10 minutes. It is normal that temperature rises. This mixture is called sodium methoxide. Now make sure the non edible oil is in a vessel large enough (at least 150% of its volume), preferably with a valve at the bottom, and heat it to about 60 °C, then stop heating. Then add the methoxide mixture and make sure it is mixed well for at least 10 minutes. Leave the vessel and let the different constituents separate by sedimentation

3. The glycerin will settle out at the bottom. After 8 to 24 hours the sedimentation is complete and the glycerine can be drained off.

4. What remains is raw biodiesel. If the reaction went well and the biodiesel is clear, it

may be used straight, although its quality may be inferior because of impurities. Water washing will remove most of these impurities.

PROPERTIES OF RAW OILS

The main important properties that do not permit the direct use of straight vegetable oils in a DI diesel engine are its high viscosity, high density, low calorific value and low cetane number. The table.1 shows the properties of methyl esters of vegetable oils that are taken in this project and compared with diesel.

Table.1 Properties of methyl esters of vegetable oils (TESTED IN ETA LAB – INDIA)

Property	Diesel	Jatropha oil	Pongamia oil	Mahua oil	Neem oil
Kinematic viscosity in cst at 40^0 C	5.032	35.38	43.67	37.18	44
Cetane no.	46.3	33.7	29.9	40	31
Calorific value in Kj/kg	44000	38833	36258	38863	34100
Pour point(^{0}C)	-12	2	5	15	
Density at 25^0C in kg/mm^3	834	916	932	904	918
Flash point (^{0}C)	78	280	215	238	214
Fire point (^{0}C)	85	291	235	250	222

EXPERIMENTAL ANALYSIS

A single cylinder, water cooled, four stroke direct injection compression ignition engine with a displacement volume of 661 cc, compression ratio of 17.5:1, developing 6.02 kW at 1800 rpm was used for the present study. The governor of the engine was used to control the engine speed. The engine had a combustion chamber with overhead valves operated through push rods. Cooling of the engine was accomplished by supplying water through the jackets on the engine block and cylinder head. The injection timing recommended by the manufacturer was 27^0 BTDC (spill). The governor used to maintain constant speed under

varying load conditions, which control the fuel flow as load changes. The engine had an open combustion chamber with overhead valves operated through push rods. The engine is coupled with eddy current dynamometer. The overall view of the experimental engine setup is shown in Fig.1.The experimental engine specification is shown in table.2

Fig.1 Experimental engine setup

Table.2 experimental engine specification

Manufacturer	Kirloskar oil engines Ltd.
Model	SV1
Maximum Power	8 HP
Max brake power	6.02 kW
Speed	1800 rpm
Compression Ratio	17.5:1
Lubrication system	Forced feed system
Bore and stroke	87.5 x 110 (mm)
Method of cooling	Water cooled
Flywheel diameter	1262 mm

TESTING PROCEDURE

The engine was started and warmed-up at low idle, long enough to establish the recommended oil pressure, and was checked for any fuel, oil leaks. After completing the warm-up procedure, the engine was run on no-load condition and the speed was adjusted to 1800 rpm by adjusting the fuel injection pump. The engine was run to gain uniform speed after which it was gradually loaded. The experiments were conducted at the torque level viz. 0, 3, 6, 9, 12, 15 kg (Because it is dynamometer torque specification for better results). For each load condition, the engine was run at a minimum of 5 minutes and data were collected during the last 2-minute of operation. Simultaneously, engine exhaust emissions (CO, HC, NO_x and smoke) were determined.

RESULTS AND DISCUSSION

The test engine is run with the different fuels and the time taken for 10 cc fuel consumption is calculated. The values are tabulated and calculations are done for brake thermal efficiency and specific energy consumption. The comparison graphs are as follows.

EFFICIENCY CURVES

Comparison of efficiency of Diesel with biodiesel blends is shown in Fig.2, Fig.3 and Fig.4.It is seen that the efficiency of diesel is maximum compared with other biodiesels at all loads. However, among the different biodiesels, Jatropha shows better efficiency than the other oils. The efficiency trend at 20% blend of biodiesel is as J20 > P20 > N20 > M20. The trend for other blends is similar to that for 20 - blend. As the load increases, the efficiency too increases. This is due to the reduced calorific value and increased viscosity of Jatropha compared with diesel. For all the biodiesels, Pongamia, Mahua and Neem, the 20% blend shows less deviation than 40% which in turn deviates less when compared with pure biodiesel. The efficiencies are as given.

P20 – 25.9%, P40 – 23.5%, P100 – 21.9%,
N20 – 25.7%, N40 – 22.7%, N100- 20.5%
M20 – 22.8%, M40 – 22.1%, M100 –19.2%.

The properties of this blends are taken by volumetric basis in which for example

(P20 = 80% of diesel + 20% of pongamia)

Thus, Jatropha shows better efficieny among the different oils and 20% blend is optimum for usage without damage to engine parts.

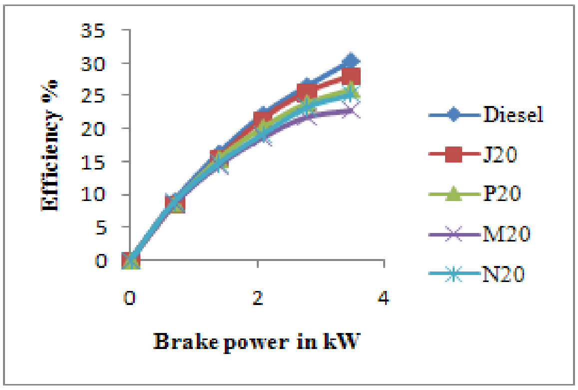


Fig.2 Comparison of efficiency of Diesel, J20, P20, M20, N20:

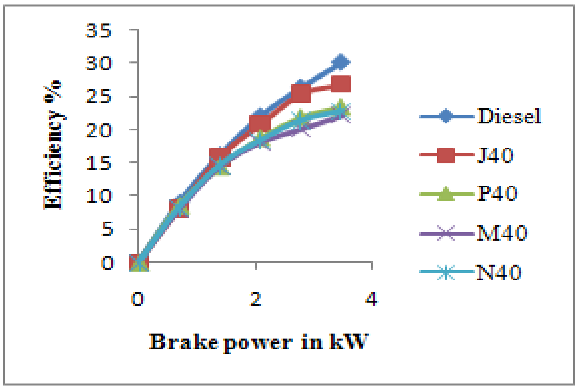


Fig.3 Comparison of efficiency of Diesel, J40, P40, M40, N40:

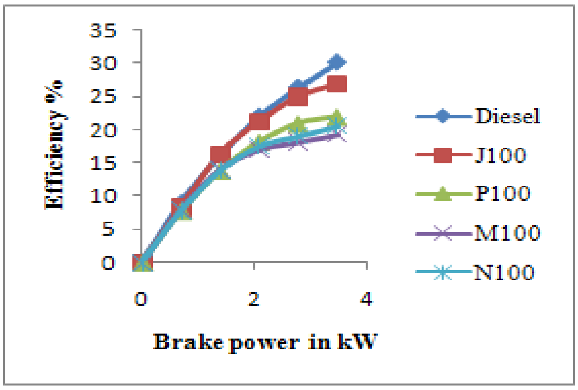


Fig.4 Comparison of efficiency of Diesel, J100, P100, M100, N100:

HC EMISSION CURVES

The emissions were measure by crypton five gas analyser fig.B.

Manufacturer	SMS Autoline Equipments private limited
Type	Crypton 290 five gas analyser
Ranges	CO - 0 to 10 % CO_2 - 0 to 20 % HC - 0 to 10000 PPM O_2 - 0 to 25 NO_x - 0 to 5000 PPM
Resolution	CO - 0.01 % CO_2 - 0.10 % HC - 1PPM O_2 - 0.01 % NO_x - 1 PPM
Principle	CO - NDIR CO_2 - NDIR HC - NDIR O_2 - Electrochemical NO_x - Electrochemical

Fig.B. specifications of gas analyser

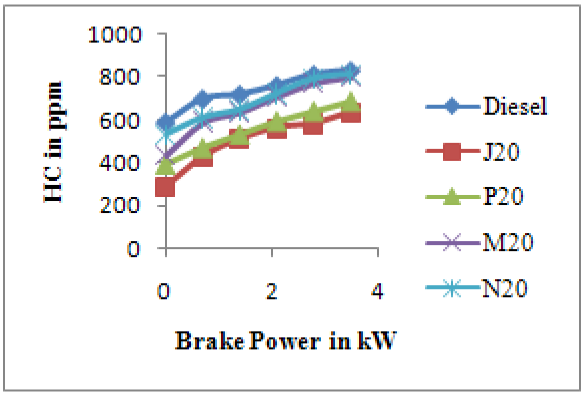


Fig.5 Comparison of HC emissions of Diesel, J20, P20, M20, N20:

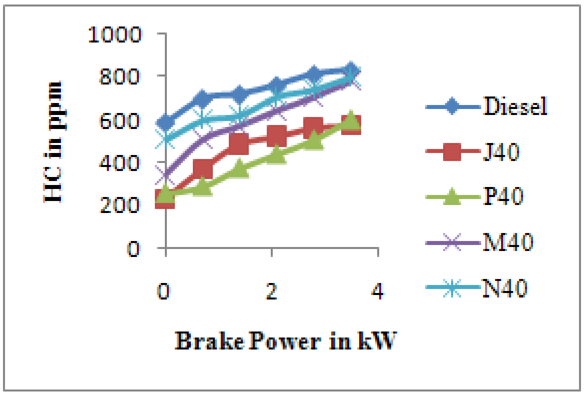


Fig.6 Comparison of HC emissions of Diesel, J40, P40, M40, N40:

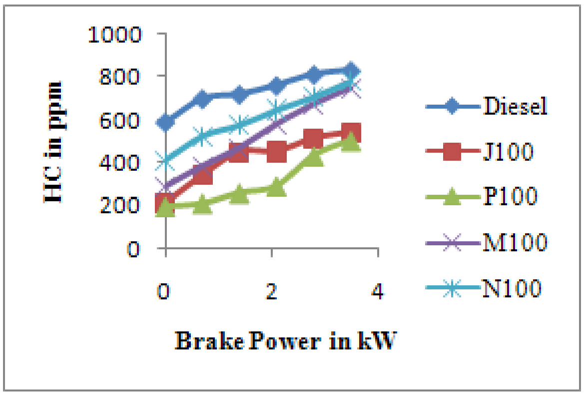


Fig.7 Comparison of HC emissions of Diesel, J100, P100, M100, N100:

Comparison of HC emissions of Diesel with biodiesel blends is shown in Fig.5, Fig.6 and Fig.7.It is seen that the HC emissions for biodiesel blends is drastically reduced when compared with diesel. This is due to the fact that all the biodiesels contain oxygen in their chemical formula. This favors better combustion when compared with diesel. Hence, HC emissions are very less for biodiesel. These emissions vary in the fashion, diesel > N20 > M20 > P20 > J20. The trend for other blends is similar to that for 20 - blend.

CO EMISSION CURVES

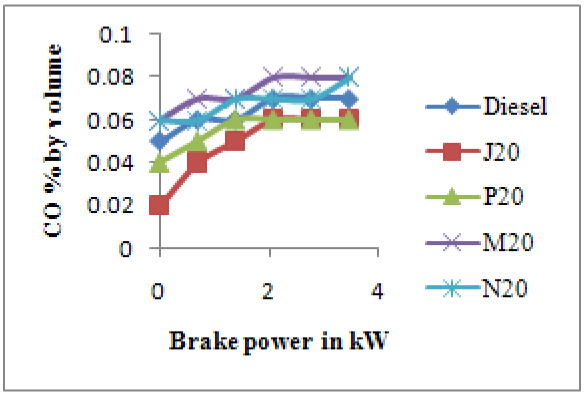


Fig.8 Comparison of CO emissions of Diesel, J20, P20, M20, N20:

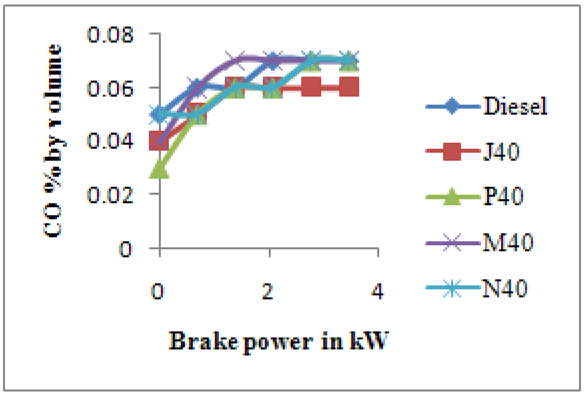


Fig.9 Comparison of CO emissions of Diesel, J40, P40, M40, N40:

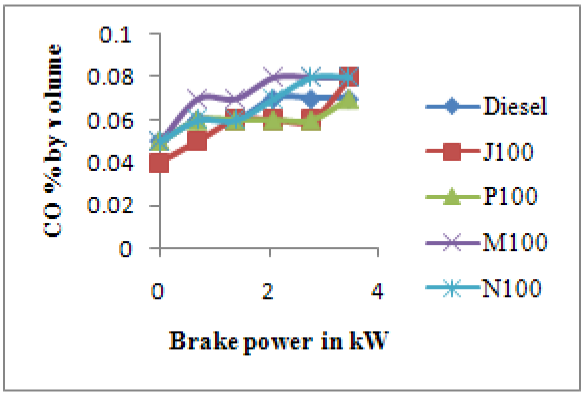


Fig.10 Comparison of CO emissions of Diesel, J100, P100, M100, N100:

Comparison of CO emissions of Diesel with biodiesel blends is shown in Fig.8, Fig.9 and Fig.10. It is seen that the CO emissions for biodiesel blends is reducd when compared with diesel This is due to the fact that presence of oxygen content in the biodiesel This favors better combustion when compared with diesel. Hence, CO emissions are less for biodiesel. These emissions vary in the fashion, M20 > N20 >diesel > P20 > J20. The trend for other blends is similar to that for 20 - blend.

NO_X EMISSION CURVES

Comparison of NO_x emissions of Diesel with biodiesel blends is shown in Fig.11, Fig.12 and Fig.13. As stated, the presence of oxygen in the biodiesel has led to complete combustion of biodiesels better than diesel. As a result, the adiabatic flame temperature or the maximum temperature inside the cylinder is more in case of biodiesels than diesel. Hence this catalyzes the reactions for oxidation of nitrogen and hence NO_x emissions are more for biodiesels. It is seen that the NO_x emissions increase with respect to load. These emissions vary in the fashion, diesel < J20 < P20 < M20 < N20. The trend for other blends is similar to that for 20 - blend.

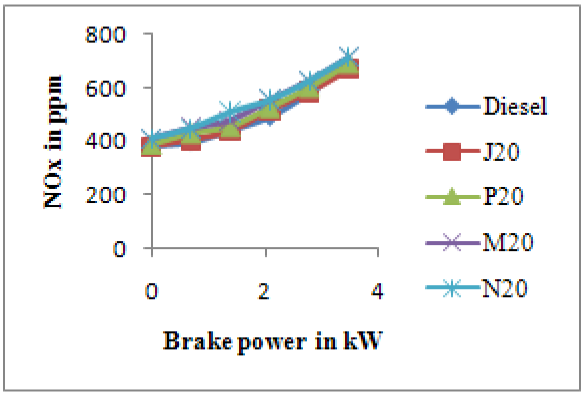


Fig.11Comparison of NO_x emissions of Diesel, J20, P20, M20, N20:

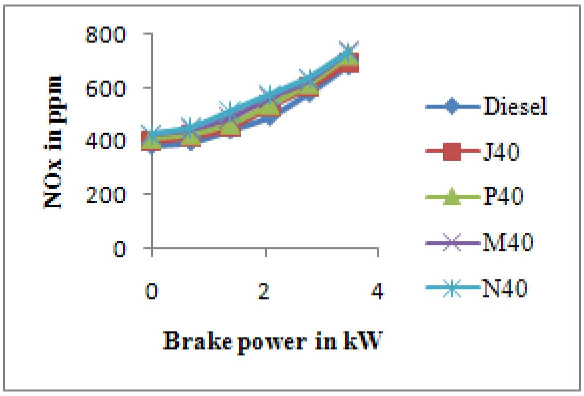


Fig.12 Comparison of NO_x emissions of Diesel, J40, P40, M40, N40

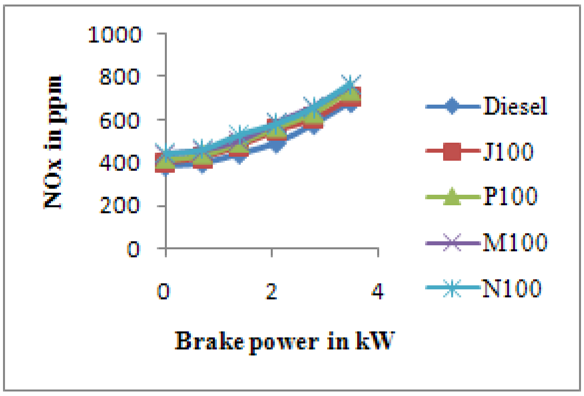


Fig.13Comparison of NO_x emissions of Diesel, J100, P100, M100, N100

CONCLUSION

The following conclusions are made from the study,

– Performance of Jatropha biodiesel is better which is then followed by pongamia oil, neem oil and mahua oil.

- Biodiesels show better performance in 20% blend with 80% diesel.
- Biodiesels show low emissions of CO and HC when compared with diesel.
- However, NO_x emissions increase for biodiesels than diesel. In future we will use SCR and EGR for reducing the NOx emissions.
- Jatropha biodiesel has low emissions than biodiesels obtained from other oils.

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