EXPERIMENTAL INVESTIGATION OF PERFORMANCE AND EMISSION CHARACTERISTICS OF DIFFERENT VEGETABLE METHYL ESTER OPERATED DI COMPRESSION IGNITION ENGINE

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The methyl esters of vegetable oils known as biodiesel are becoming increasingly popular because of the low environmental impact and potential as a green alternative fuel for diesel engine and they would not require significant modification of existing engine hardware. Methyl esters of Jatropha (JME), Pongamia (PME) and Mahua (MME) are derived through transesterification process. Experimental investigations have been carried out for methyl esters of different oil in blends with diesel of different proportions. It was observed that a diesel engine runs successfully on a blend 20% biodiesel and 80% diesel fuel without affecting engine performance. Methyl esters from Jatropha, with properties close to diesel, show better performance and emission characteristics, followed by esters of Pongamia and Mahua. Hence Jatropha blend can be used in existing diesel engines without compromising the engine performance.

Keywords: Jatropha methyl esters, NOx, HC, CO, Transesterification, Pongamia, Mahua, performance, emission, combustion.

1. Introduction

Fossil fuels like diesel fuel is highly demanded, shortage and also its increasing cost for that reason an alternate source of fuel for diesel is very much needed. It has been found that vegetable oil hold special promise in this regard, since they can be produced from the plants grown in rural areas. [1] Vegetable oil from crops such as soyabean, peanut, sunflower, Jatropha, mahua, neem, rape, coconut, karanja, cotton, mustard, linseed and castor have been tried in many parts of the world, which fulfil the present need.[2] Just like petroleum diesel, biodiesel operates in compression ignition(diesel) engine, and essentially require very little or no engine modifications. [3] Biodiesel is meant to be used in standard diesel engines and is thus distinct from vegetable and waste oils used to fuel converted diesel engines. Biodiesel can be produced from non-edible oils obtained from plant species [karanja(Pongamia pinnata), Jatropha(Jatropha curcas),mahua(Madhucaindica), neem (Azadirachtaindica) etc. [4,5] Use of biodiesel in conventional diesel engines results in substantial reduction in

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emission of unburnedhydrocarbons, carbonmonoxide and particulate. [7] Neatvegetable oil has highest potential of reducing lifecycle greenhouse gas emissions as compared to biodiesel and diesel. [8] India's selfsufficiency in petroleum oil as consistently declined 60% in 1950 to 30% in 2010 and is expected to go down to 8% by 2020. [9,10] As India is deficient in edible oil and demand for edible oil exceeds supply, the Government decided to use non-edible oil from Jatropha oil seeds as biodiesel feedstock. [11,13] As per the Government of India's Vision document 2020 cultivating Jatropha (10million ha) would generate 7.5million tonnes of fuel a year, creating year round jobs for 5million people.

2. Transesterification of vegetable oils:

Transesterification is the process of using an alcohol (e.g. methanol or ethanol) in the presence of catalyst such as sodium hydroxide (NaOH) or potassium hydroxide (KOH), which chemically breaks the molecule of the raw oil into methyl or ethyl esters with glycerol as a by-product, which reduces the high viscosity of oils. This method also reduces the molecular weight of the oil to 1/3 of its original value, and increase the volatility and cetane number comparable to diesel fuel. Conversion not greatly affects the gross heat of combustion.

Vegetable oil consists of triglycerides, free fatty acids and fat accompanying substances which are mostly removed with refining. A triglyceride is a compound, in which one molecule of glycerin, a trivalent alcohol is estered with three fatty acid molecules. Mostly, these three fatty acids are different. Transesterification is the change of the trivalent glycerin molecules against three molecules of monovalent alcohol methanol. Each is a monoester. In the most vegetable oil, fatty acid with 16 and 18 carbon atoms predominate.

Experimental setup:

The schematic diagram of the engine test rig used is shown in fig.1. The engine is fully equipped with measurements of all operating parameters.A smoke meter is used to determine the smoke density of the engine exhaust. A gas analyzer is used to measure the exhaust gas composition. The exhaust gas temperatures are measured with the help of K type thermocouple.

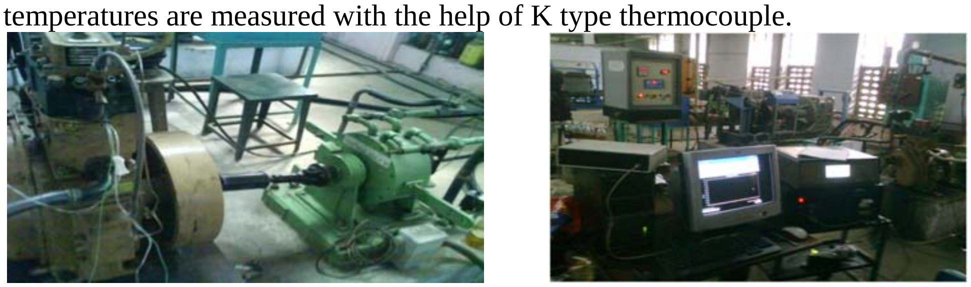


Fig.1. Experimental setup

A. Specifications of the apparatus:

In the test rig there are several instruments/ equipment have been used for the purpose of the experiment. Brief specifications of the instruments are given below.

i. Diesel engine:

Manufacturer : Kirloskar oil engines limited
Type of Engine : Vertical, 4-Stroke Single cylinder
Model : SV1; Maximum Power : 8 HP
Max brake power : 5.09 kW; Speed : 1800 rpm
Compression Ratio : 17.5:1; Bore and stroke : 87.5 x 110 (mm)
Injection pressure : 200 bar

ii. Smoke meter:

Smoke meter is used to determine the smoke density of the engine exhaust. The AVL 437 smoke meter has been designed for simple one man operation either from alongside a vehicle for either free acceleration or steady state test procedures. Control is via a compact and rugged handset with a digital L.C.D. display. Any out of range parameters are automatically flagged to the operator. The brief specifications of the smoke meter are given below:

Type : AVL 437 smoke Meter; Make : AVL India Pvt. Ltd
Measuring range : 0 to 100 HSU

iii. Exhaust gas analyzer:

Manufacturer : SMS Autoline Equipments private limited
Type : Crypton 290 five gas analyzer

B. Testing Procedure:

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. The engine was run on no-load condition and speed was adjusted to 1800 rpm by adjusting fuel injection pump. Engine was run to gain uniform speed, after which it was gradually loaded. Experiments were conducted at different torque levels (0, 8, 16, 24 and 32 Nm). The engine was run for 10 minutes in each torque and data were collected during last 3 minutes. The experimental uncertainties are shown in Table.1

Table 1

Experiment Uncertainties

Parameters	**Systematic Errors (±)**
Speed	1 ± rpm
Load	± 0.1 N
Time	± 0.1 s
Brake power	± 0.15 kW
Temperature	± 1°

Pressure	± 1 bar
NO_x	± 10 PPM
CO	± 0.03%
CO2	± 0.03%
HC	± 12 PPM
Smoke	± 1 HSU

4. Results and discussion

Test engine was run with different fuels and time for 10cc fuel consumption was calculated. Among three biodiesels Jatropha shows lesser viscosity than other biodiesels as shown in Table 2.

Table 2

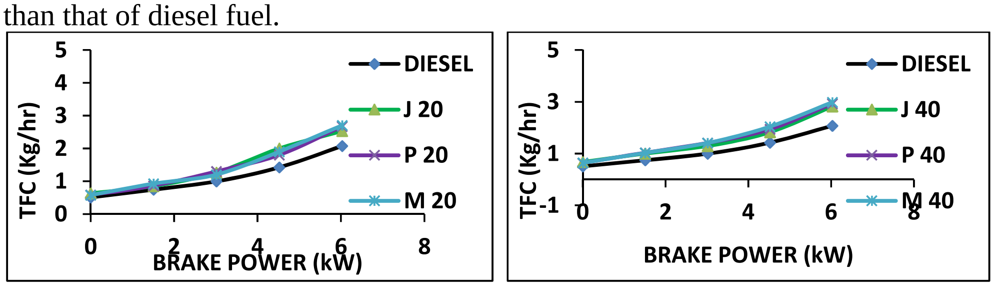
Properties of diesel and biodiesels

PROPERTY	Diesel	Jatropha oil	Pongamia oil	Mahua oil
Kinematic viscosity in cst at 40^0 C	3.1	4.66	4.84	6.4
Lower Heating value in KJ/kg	43200	36694	36409	34597
Density at 15^0C in kg/mm^3	830	876	904	910
Cetane no.	46.4	48	50	52
Flash point (^{0}C)	56	85	87	91
Fire point (^{0}C)	64	92	96	104

A. Performance characteristics of Diesel, JME, PME and MME:

i. Total fuel consumption (TFC)

Fig 2 shows that TFC of diesel is minimum compared with other biodiesel at all loads. Among biodiesel, Jatropha showed better TFC than other oil. TFC trend at 20% blend of biodiesel is as J20>P20>M20. For other blends, trend is similar to that for 20-blend.The TFC for J20 is increased by 7.4% when compared to other biodiesel. As load increases, TFC too increases and it may be due to higher specific gravity and lower heating value of the biodiesel fuel as compared with diesel fuel. The lower heating value of the Jatropha biodiesel was about 8% lower than that of diesel fuel.



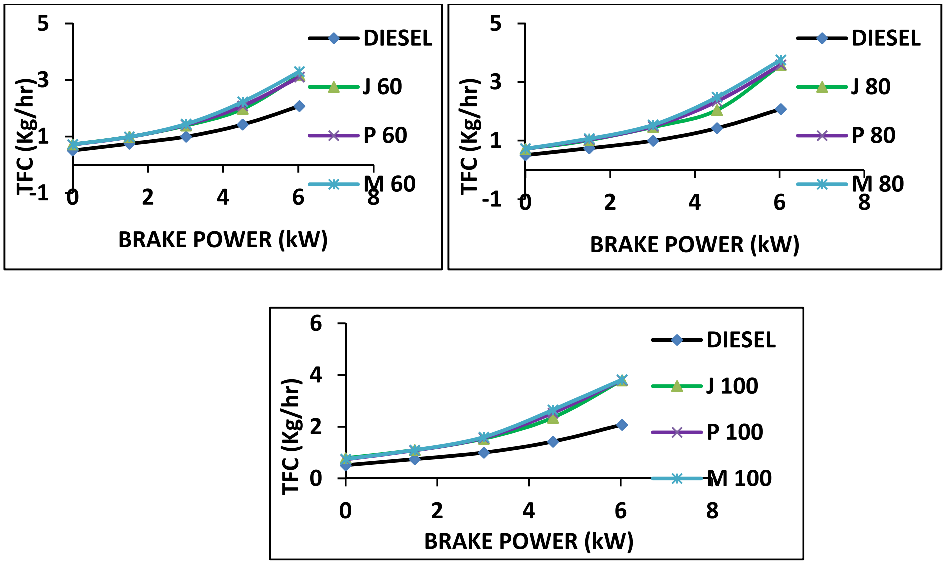
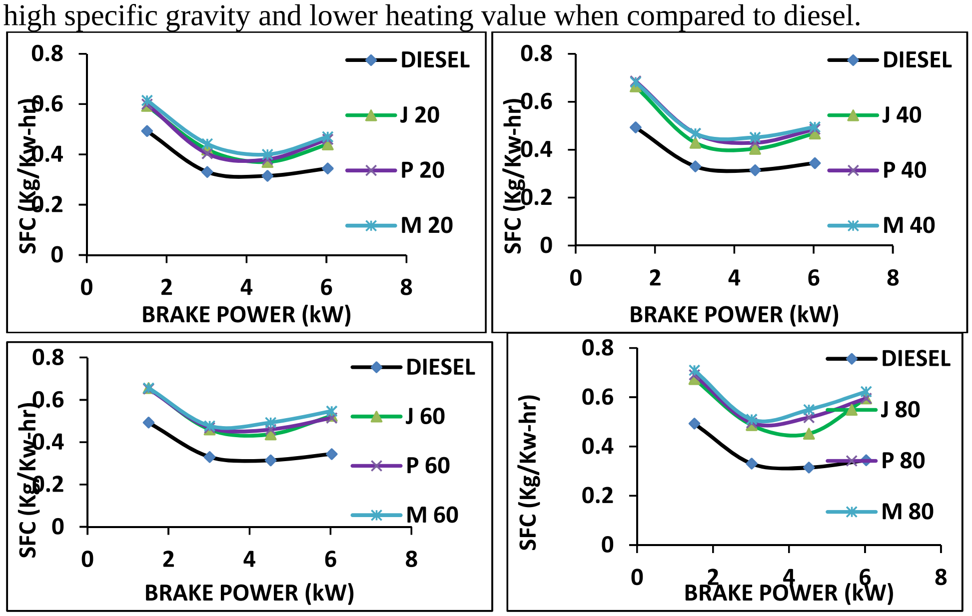


Fig.2. Brake power Vs TFC for different blends

ii. Specific fuel consumption (SFC)

Fig 3 shows that SFC of diesel is minimum compared with other biodiesels at all loads. Among biodiesels, Jatropha showed better SFC than other oils. SFC trend at 20% blend of biodiesel is as J20<P20<M20. For other blends, trend is similar to that for 20-blend.The SFC for J20 is decreased by 18.19% when compared to that of other biodiesels. This is due to complete combustion and also excess oxygen, high specific gravity and lower heating value when compared to diesel.



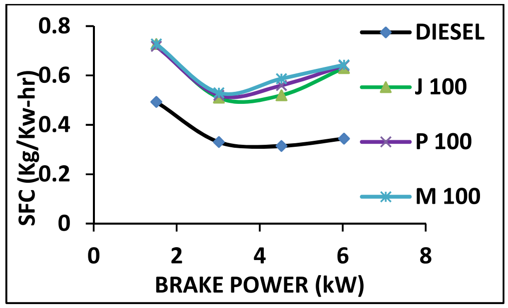
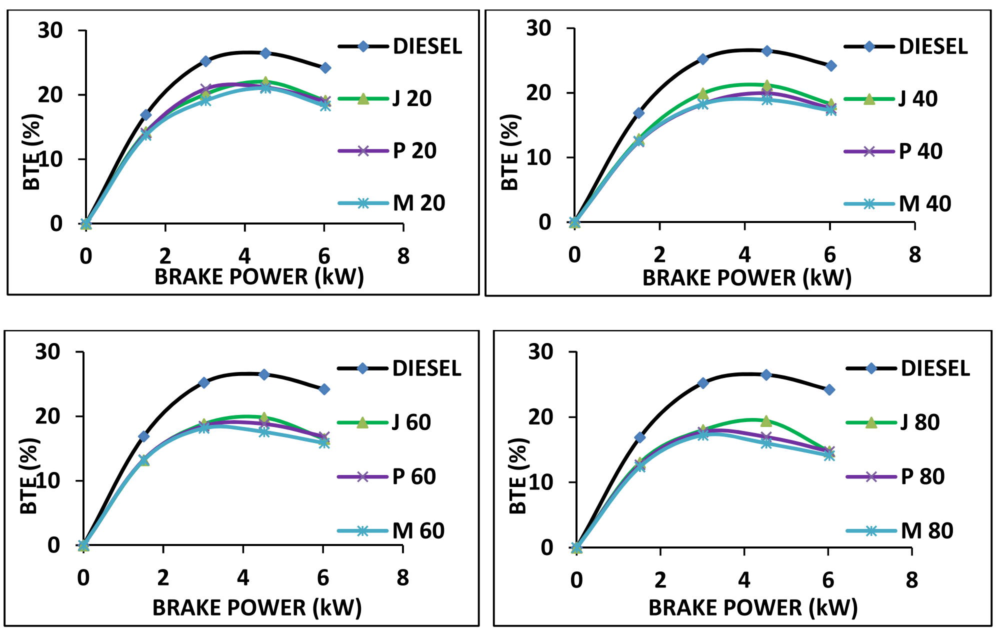


Fig.3. Brake power Vs SFC for different blends

iii. Brake thermal efficiency (BTE)

Fig 4 shows that BTE of diesel is maximum compared with other biodiesels at all loads. Among biodiesels, Jatropha showed better BTE than other oil. BTE trend at 20% blend of biodiesel is as J20>P20>M20. For other blends, trend is similar to that for 20-blend.The BTE is increased by 5.26% when compared to that of other biodiesels. As load increases, BTE too increases, may be due to availability of O_2, which helps in complete combustion of the fuel.



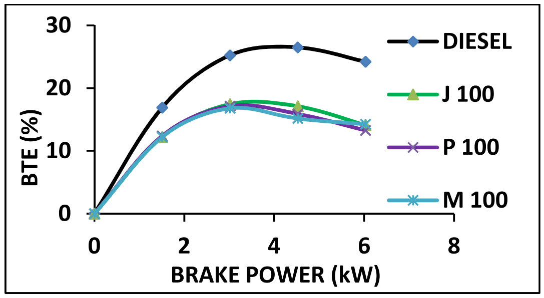
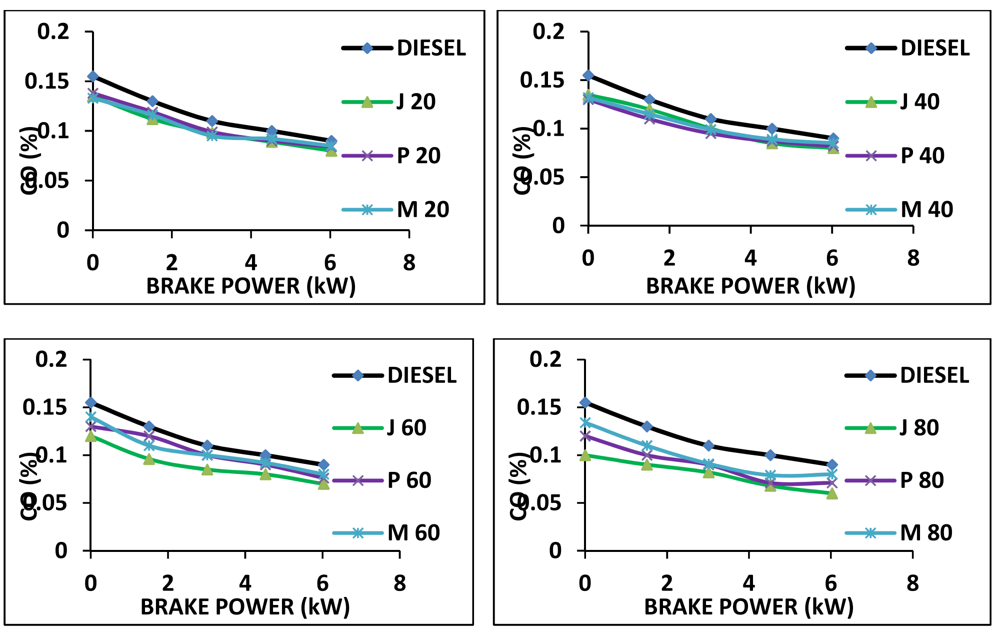


Fig.4. Brake power Vs BTE for different blends

B. Emission characteristics comparison of Diesel, JME, PME and MME:

i. Carbon monoxide (CO)

Fig 5 shows that among all the three biodiesels, Jatropha has lower CO emissions. CO trend at 20% blend of biodiesel is as J20<P20<M20. For other blends, trend is similar to that for 20 – blend. The CO emission for J20 is decreased by 15% when compared to that of other biodiesels. It is commonly accepted that CO emission reduce when using biodiesel due to lower carbon to hydrogen ration. This is also due to more oxygen molecules present in the biodiesel, leads to complete combustion which in turn helps in reduction of CO.



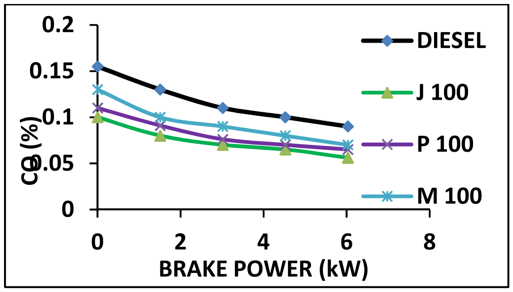
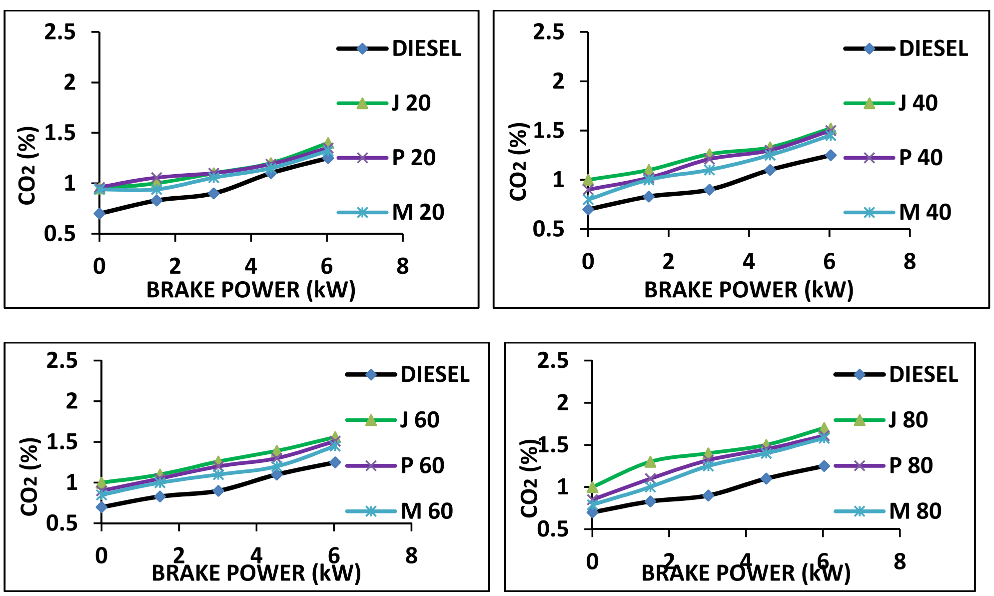


Fig.5. Brake power Vs CO for different blends

ii. Carbon Di-oxide (CO_2)

Fig 6 shows that among all three biodiesel, CO_2 emission of Jatropha is higher than that of other biodiesels. CO_2 trend at 20% blend of biodiesel is as J20>P20>M20. The CO_2 for J20 is increased by 15.38% when compared to that of other biodiesels. This is due to biodiesel is generally a low carbon fuel and has a lower elemental carbon to hydrogen ratio than diesel fuel. For other blends, trend is similar to that of 20-blend.



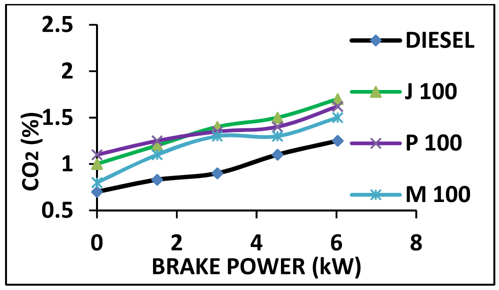
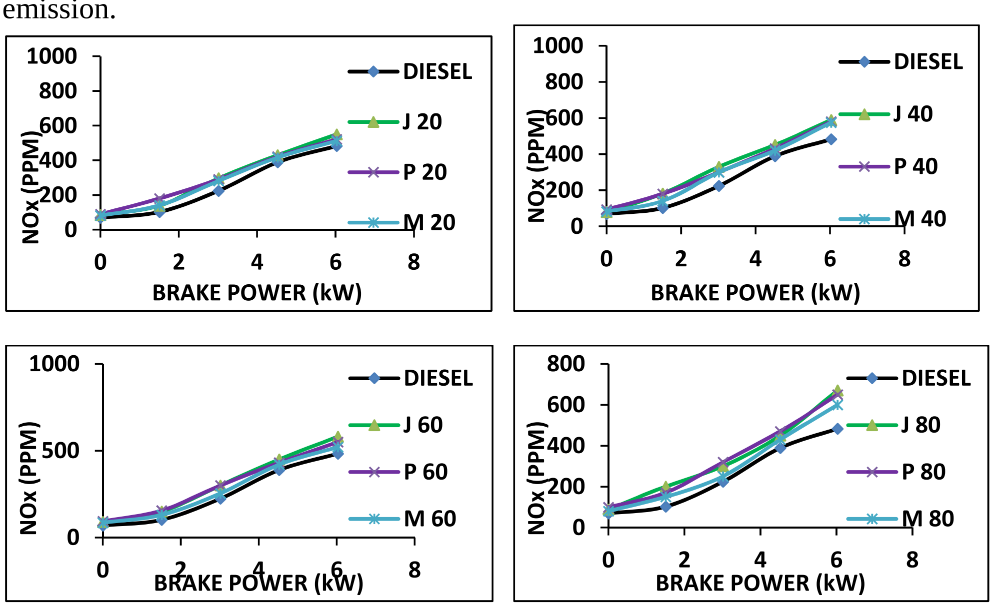


Fig.6. Brake power Vs CO2for different blends

iii. Oxides of Nitrogen (NO_x)

Fig 7 shows that NOx emission of diesel is minimum when compared with other biodiesels at all loads. Among biodiesels, Jatropha showed maximum NOx emissions than other oils. NOx emission trend at 20% blend of biodiesel is as J20>P20>M20.The NO_x emission for J20 is increased by 12.32% when compared to that of other biodiesels. This is due to the presence in biodiesel of oxygen, which leads to complete combustion of biodiesel than diesel. As a result, maximum temperature inside cylinder is more in case of biodiesel. This induces reactions for oxidation of nitrogen and hence NOx emissions more for biodiesel. Further the NOx emission increases with load. However, at 20% blend the NOx emission is minimum when compared with other blends. Moreover, cetane number and different injection characteristics also have an effect of NOx emission.



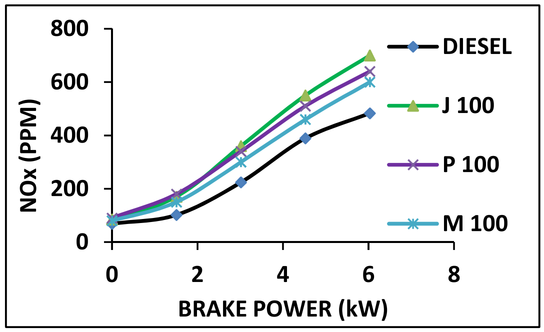
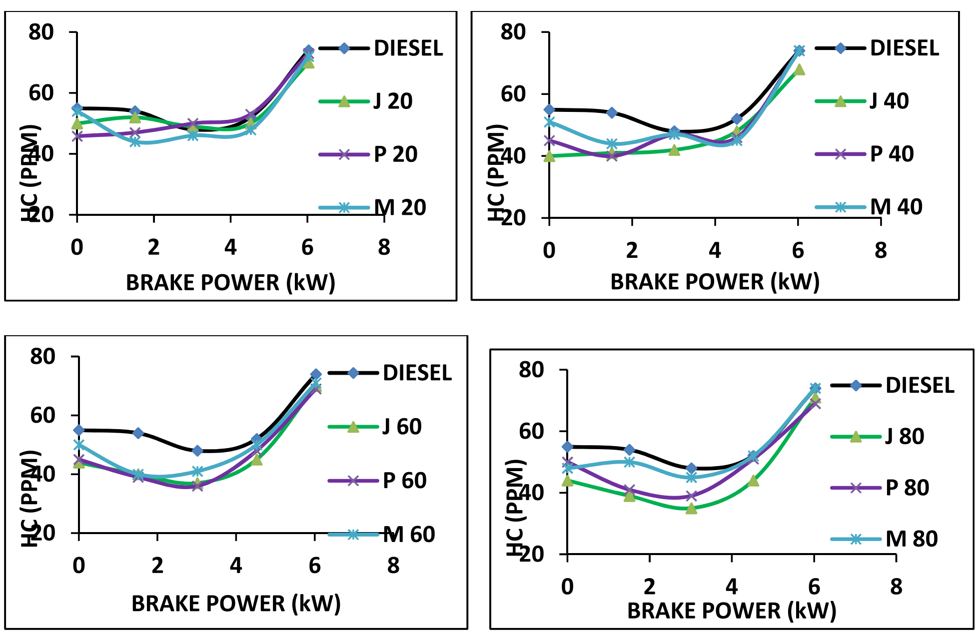


Fig.7. Brake power Vs NOx for different blends

iv. Hydrocarbon (HC)

Fig 8 shows that HC emission and it is minimum compared with other biodiesel at all loads. Among the three biodiesel, Jatropha showed minimum HC emission than the others. HC emissions trend at 20% blend of biodiesel is as J20<P20<M20.The HC emission for J20 is decreased by 12% when compare to that of other biodiesels. Most of the researchers showed that HC emission for biodiesel reduce with increase of biodiesel content. This may be because biodiesel contain more oxygen, which leads to better combustion.



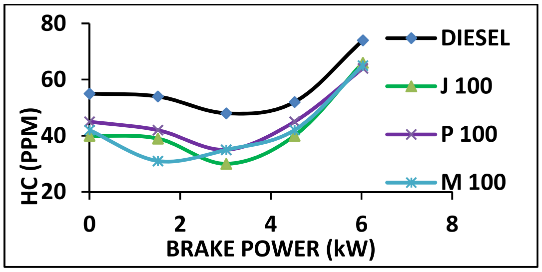


Fig.8. Brake power Vs HC for different blends

C. Economic analysis of Jatropha biodiesel:

Cost of raw Jatropha oil = Rs. 22/ litre; Biodiesel processing cost= Rs. 9/ litre;Cost of production = Rs. 31/ litre; Less return from crude glycerol = Rs. 3/litre; Net cost of production = Rs. 28/ litre; Dealer's margin = Rs. 1/ litre; Profit = Rs. 3/ litre; Sales price of biodiesel = Rs. 32/ litre.

From the above data, the cost of Jatropha biodiesel is Rs 32/ litre which isless than that of Mahua and Pongamia as shown in table 3.

Table 3.

Production cost of Pongamia and Mahua

Processing Cost	*Unit*	*Pongamia*	*Mahua*
Seed collection	Rs. per kg	15	12
4 kg seeds produce 1 kg oil	Rs. per kg	60	48
Oil expeller running cost	Rs. per kg	5	5
By-product – oilcake	Rs. per kg	-16	-8
Packing and storage	Rs. per kg	3	3
Total cost	Rs. per kg	52	48

5. Conclusions

The various performance and exhaust emission were studied for the different biodiesel blends. The BTE for J20 is increased by 5.26% ant the SFC is decreased by 18.19% when compared to that of other biodiesels at full load conditions. The CO and HC emission for J20 is decreased by 15% and 12% respectively when compared to that of other biodiesel. Further, the NO_x emission for J20 is increased by 12.32% when compared to that of other biodiesels at full load conditions. Further Jatropha is suitable to cultivate in tropical country and moreover India is a suitable place to cultivate Jatropha. It also saves around 7.3 X 10^6 tons of diesel per year. It is concluded that the biodiesel shows better performance at 20% blend with 80% diesel. Among the different biodiesel blends, Jatropha shows the best performance and reduction in emissions at 20% blend without doing any engine modification.

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