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Performance and Emission Characteristics of Mahua and Linseed Biodiesel Operated at Varying Injection Pressures on CI Engine

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ABSTRACT

Biodiesel derived from nonedible feed stocks such as Mahua, Jatropha, Pongamia, Linseed are reported to be feasible choices for developing countries including India. This paper presents the results of investigation of performance and emissions characteristics of diesel engine using Mahua and Linseed biodiesel. In this investigation, the blends of varying proportions of Mahua biodiesel with diesel (M25, M50, M75, M100) and Linseed biodiesel with diesel(L25, L50, L75, L100) were prepared, analyzed, and compared the performance and exhaust emission with diesel using a single cylinder diesel engine. The brake thermal efficiency, brake-specific fuel consumption, CO and HC were analyzed.

In the investigation it is found that the combined increase of injection pressure increases the BTHE and reduces BSFC while having lower emissions for Mahua biodiesel as compared to Linseed biodiesel. For small sized direct injection constant speed engines used for agricultural applications (5.2 kW), the optimum combination was found at injection pressure of 160 bar with Linseed (L100), whereas the harmful pollutants such as HC, CO, are reduced in the Mahua biodiesel compared to Linseed biodiesel fuel.

Key words: Injection timing, injection pressure, Mahua biodiesel, Linseed bio diesel, performance, emission, combustion characteristics, Diesel engine

Abbreviations used:
BSFC: Brake specific fuel consumption
BTHE: Brake thermal efficiency
M25: Blend 25% Mahua Biodiesel and 75% diesel
M50: Blend of 50% Mahua Biodiesel and 50% diesel
M75: Blend of 75% Mahua Biodiesel and 25% diesel
M100: 100% Mahua Biodiesel.
L25: Blend of 25% Linseed Biodiesel and 75% diesel
L50: Blend 50% Linseed Biodiesel and 50% diesel
L75: Blend of 75% Linseed Biodiesel and 25% diesel
L100: 100% Linseed Biodiesel

INTRODUCTION

With crude oil reserves estimated to last for few decades, there has been an active search for alternate fuels.The depletion of crude oil would cause a major impact on the transportation sector. Of the various alternate fuels under consideration, biodiesel, derived from vegetable oils, is the most promising alternative fuel to diesel due to the following reasons.

i) Biodiesel can be used in the existing engine without any modifications.
ii) Biodiesel is made entirely from vegetable sources; it does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues.
iii) Biodiesel is an oxygenated fuel.
iv) Emissions of carbon monoxide and soot tend to reduce.
v) The use of biodiesel can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel.
vi) Biodiesel is produced from renewable vegetable oils/animal fats and hence improves the fuel or energy security and economy independence.

A lot of research work has been carried out to use vegetable oil both in its neat form and modified form. Since India is net importer of vegetable oils, edible oils cannot be used for production of biodiesel. India has the potential to be a leading world producer of biodiesel, as biodiesel can be harvested and sourced from non-edible oils like Jatropha, Curcus, Pongamia Pinnata, Neem, Mahua, Castor, Linseed, etc. Some of these oils produced even now are not being properly utilized. Out of these plants, we are focusing Mahua and Linseed which can grow in arid and wastelands. Implementation of biodiesel in India will lead to many advantages like green cover to wasteland, support to agriculture and rural economy and reduction in dependence on imported crude oil and reduction in air pollution.

In the present investigation biodiesel is prepared from Mahua oil and Linseed oil. The performance and emission characteristics were analyzed on a four stroke single cylinder direct injection diesel engine.

Figure 1. Photograph of Linseed and Mahua Seeds

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BIODIESEL PRODUCTION

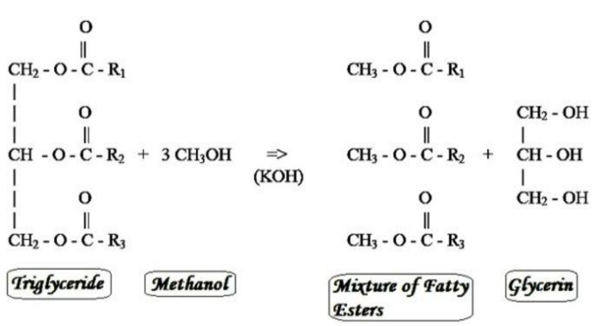
Esterfication of vegetable oil comprised heating of oil, addition of sodium hydroxide and alcohol, stirring of the mixture, separation of glycerol, and biodiesel. This esterfied vegetable oil is called biodiesel. Biodiesel properties are similar to diesel fuel as shown in the Table.1. After esterfication of Mahua and Linseed oil their properties like density, cetane number, viscosity, and calorific value are improved. These parameters induce better combustion characteristics and performance of diesel engine. The biodiesel contain more oxygen and lower calorific value compare than diesel. As a results in lower generation of hydrocarbon and carbon monoxide in the exhaust than diesel fuel. The physical and chemical properties of Mahua biodiesel and linseed biodiesel and their blends are measured as per Indian standards (IS) methods in fuel testing laboratory and tabulated in Table 1. Calorific value and viscosity are measured by Bomb calorimeter and Redwood viscometer (Petroleum Instruments India Pvt. Ltd.), respectively. The flash point and fire point are determined by Pensky-Martin's apparatus closed-cup method.

Fuel blends	Density (Kg/m³)	CV (KJ/Kg)	Viscosity at 40°C(cSt)	Flash point (°C)	Fire point (°C)
L25	850	41188	3.17	91	100
L50	866	39875	3.22	126	136
L75	870	38563	3.27	161	171
L100	880	37251	3.32	196	206
M25	858	41146	3.74	81	90
M50	862	40468	4.35	105	115
M75	876	39791	4.96	129	140
M100	894	38437	5.58	154	165

Table.1 Properties of Biodiesel blends compared with neat diesel

TRANSESTERIFICATION PROCESS

The most common way of producing biodiesel is the transesterification of vegetable oils and animal fats. Oil or fat reacts with alcohol (methanol or ethanol). This reaction is called transesterification. The reaction requires heat and a strong catalyst (alkalis, acids, or enzymes) to achieve complete conversion of the vegetable oil into the separated esters and glycerin. The reaction is shown in below.



EXPERIMENTAL SETUP AND PLAN

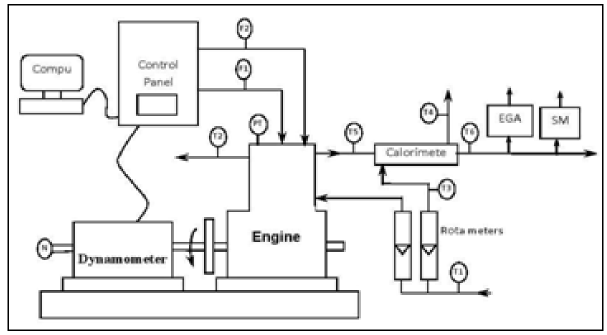


Figure 2: Schematic diagram of experimental setup

Engine specification:

Manufacturer	Kirloskar Oil Engines Ltd., India,
Model	TV–SR II, naturally aspirated
Engine	Single cylinder, DI, Four Stroke
Bore / stroke	87.5mm/110mm
Compression ratio	16.5, 17.5 and 18 (Variable)
Speed	1500 r/min, constant
Rated power	5.2 kW
Injection pressure	240 bar/23° deg BTDC
Type of sensor	Piezo electric
Response time	4 micro seconds
Crank angle sensor	1-degree crank angle

RESULT AND DISCUSSION

Experimental investigations have been carried to examine the performance and emission characteristics at different injection pressure of 160 bar, 180 bars and 200 bar. The details have been tabulated below and the graphs have been ploted. The engine was set to run at compression ratio 16.5:1, advanced injection timing 27°BTDC to arrive at the optimum for Mahua biodiesel blends (M25, M50, M75, M100) and Linseed biodiesel blends (L25, L50, L75, L100).

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1. PERFORMANCE CHARACTERISTICS

1.1 Brake *Thermal Efficiency*

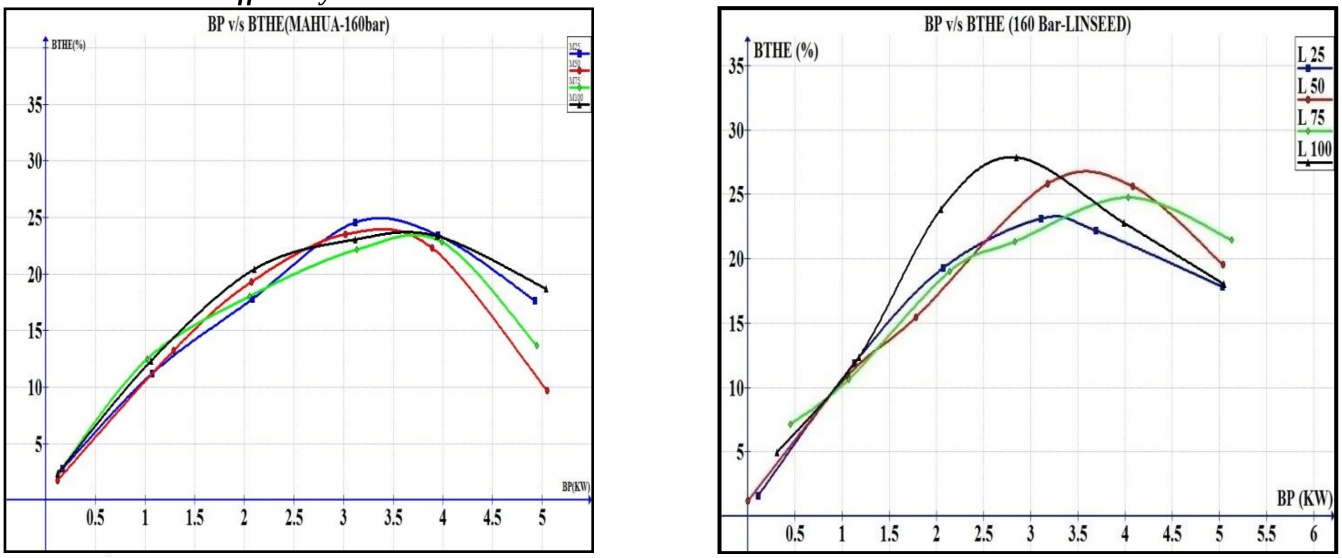

Figure 1 Comparison of BTE between Mahua biodiesel blends and Linseed biodiesel blends at 160 bar injection pressure.

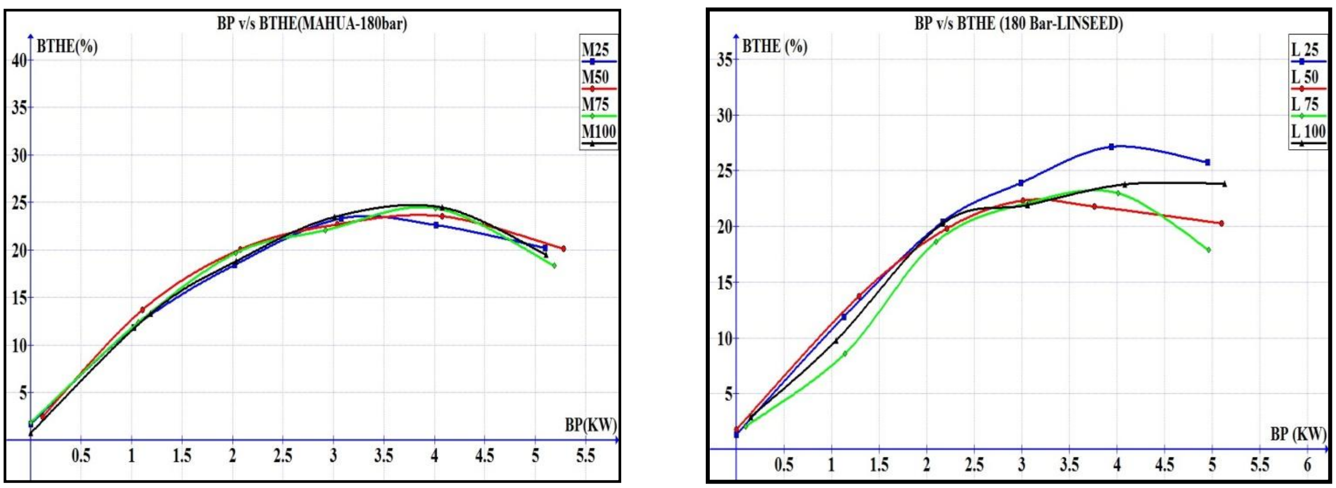

Figure 2 Comparison of BTE between Mahua biodiesel blends and Linseed biodiesel blends at 180 bar injection pressure.

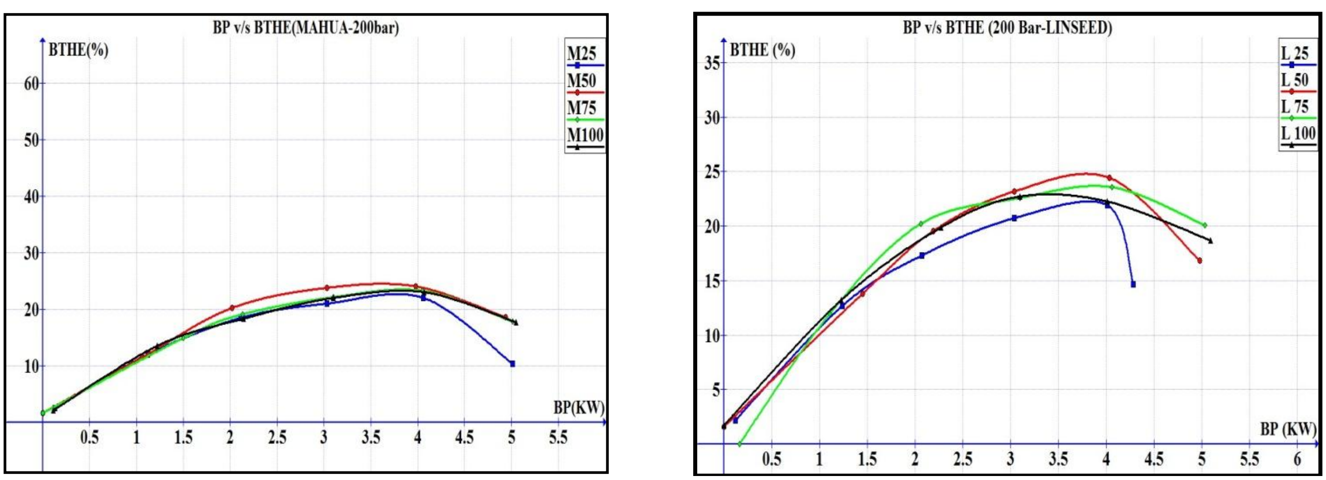

Figure 3 *Comparison of BTE between Mahua biodiesel blends and Linseed biodiesel blends at 200 bar injection pressure.*

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It is evident from Figure 3, Figure 4and Figure 5, that the overall trends of BTE characteristics of Mahua biodiesel, Linseed biodiesel, and their blends are almost similar in nature. It is observed that at any given load condition, the brake thermal efficiency of neat Mahua biodiesel (M100) and other blends (M25, M50, M75) is lower than that of Linseed biodiesel(L100) and its blends (L25, L50, L75) operation. It can be seen that as the percentage of Mahua biodiesel in the blend increases, there is more decrease in brake thermal efficiency as compared to Linseed biodiesel mode. This lower BTE of Mahua biodiesel operation is due to the combined effect of higher viscosity, higher density of Mahua biodiesel.

1. 2 ***Specific fuel consumption***

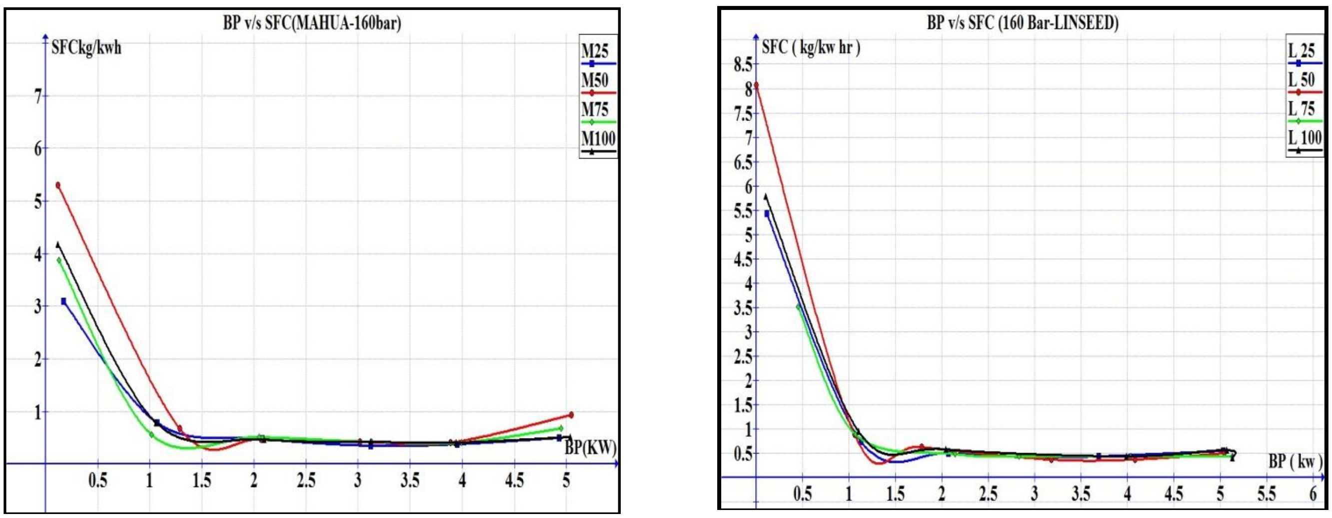

Figure 4 Comparison of SPFC between Mahua biodiesel blends and Linseed biodiesel blends at 160 bar injection pressure.

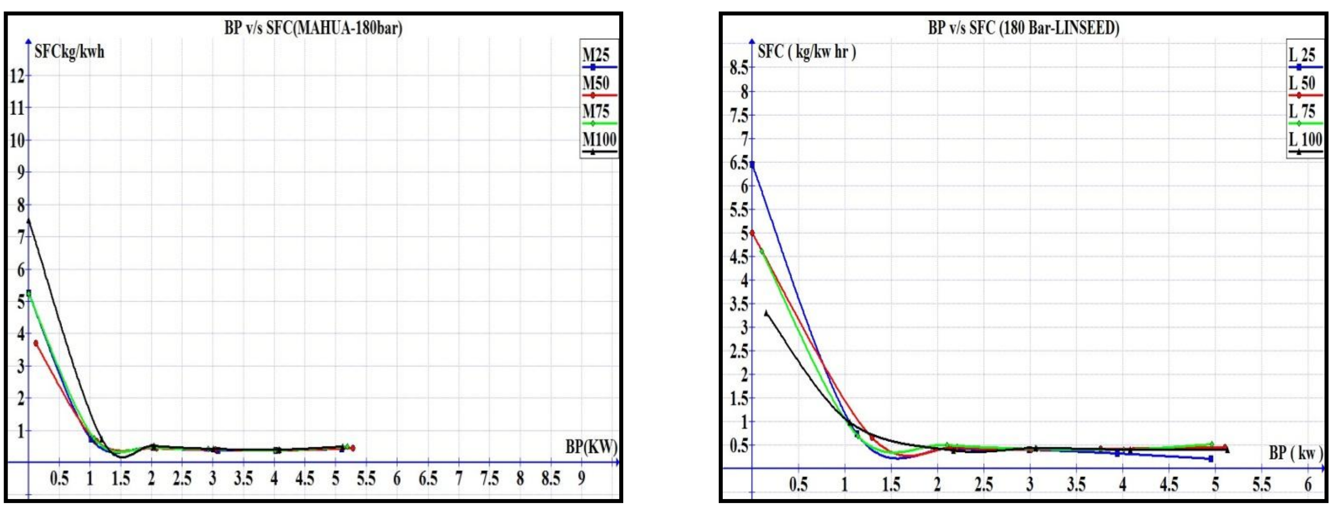

Figure 5 Comparison of SPFC between Mahua biodiesel blends and Linseed biodiesel blends at 180 bar injection pressure.

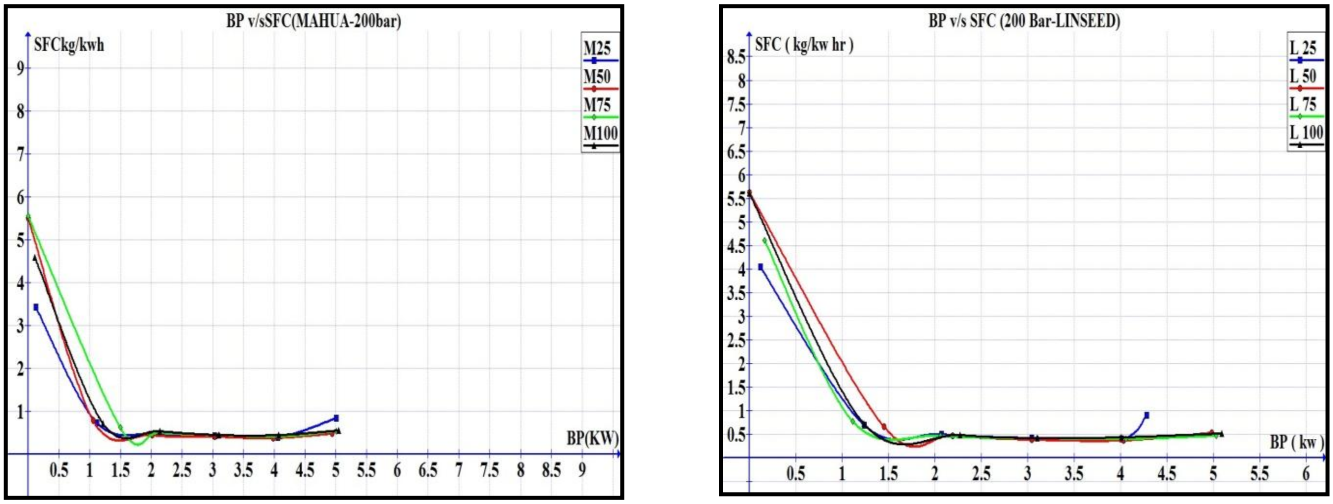

Figure 6 Comparison of SPFC between Mahua biodiesel blends and Linseed biodiesel blends at 200 bar injection pressure.

Figure 6, Figure 7 and Figure8, shows the comparison of effect of load on brake-specific fuel consumption between Mahua biodiesel and Linseed biodiesel for different blend conditions. It is seen that brake-specific fuel consumption decreases when the load is increased for all operations of Linseed biodiesel and Mahua biodiesel and their blends. However, the rate of decrease in brake specific fuel consumption is more during lower loads up to 50% than that of higher loads (50 to 100%). It can also be observed that brake-specific fuel consumption increases when Linseed biodiesel proportion in the blend is increased for any given load, but the increase in brake-specific fuel consumption for M100 operation (neat Mahua biodiesel) is much more than that of other blends and diesel operations at higher load conditions.

2. EMISSION CHARACTERISTICS

2.1 *Carbon monoxide content (%)*

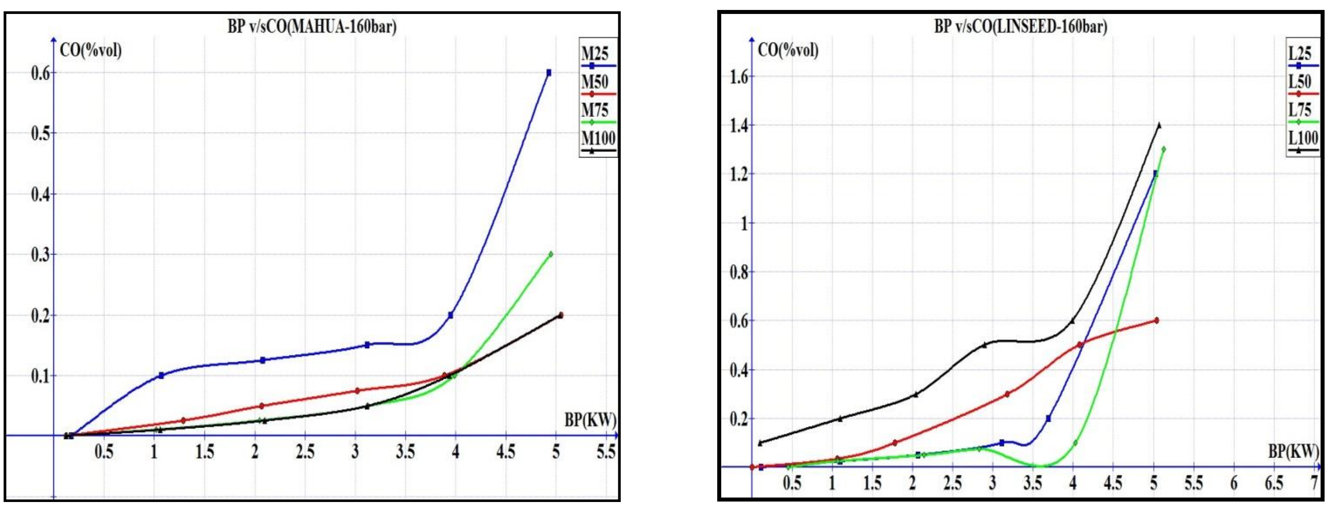

Figure 7 Comparison of CO between Mahua biodiesel blends and Linseed biodiesel blends at 160 bar injection pressure.

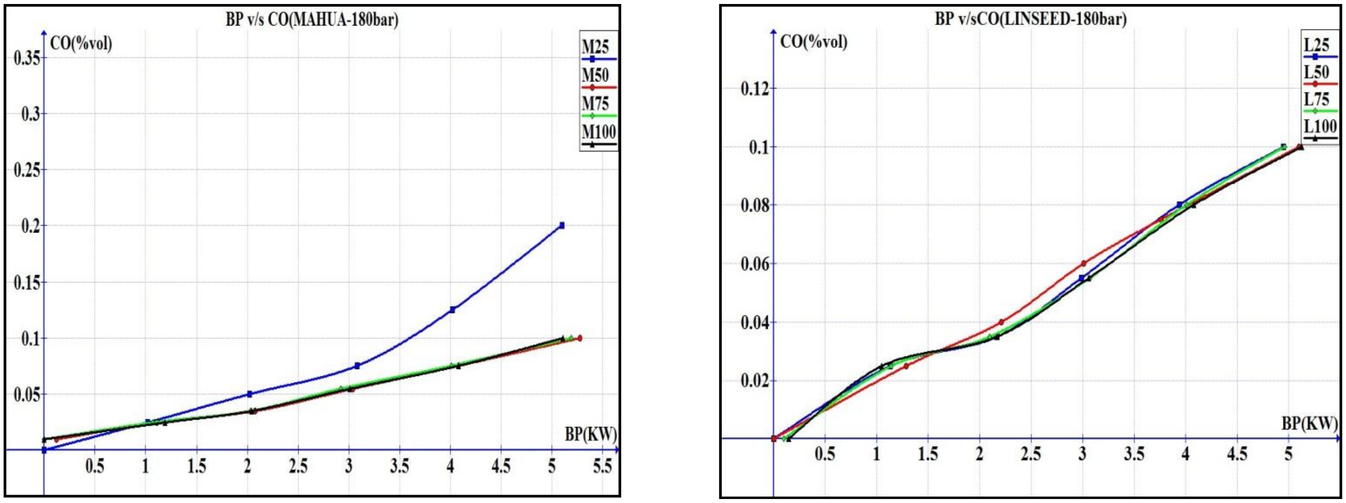

Figure 8 Comparison of CO between Mahua biodiesel blends and Linseed biodiesel blends at 180 bar injection pressure.

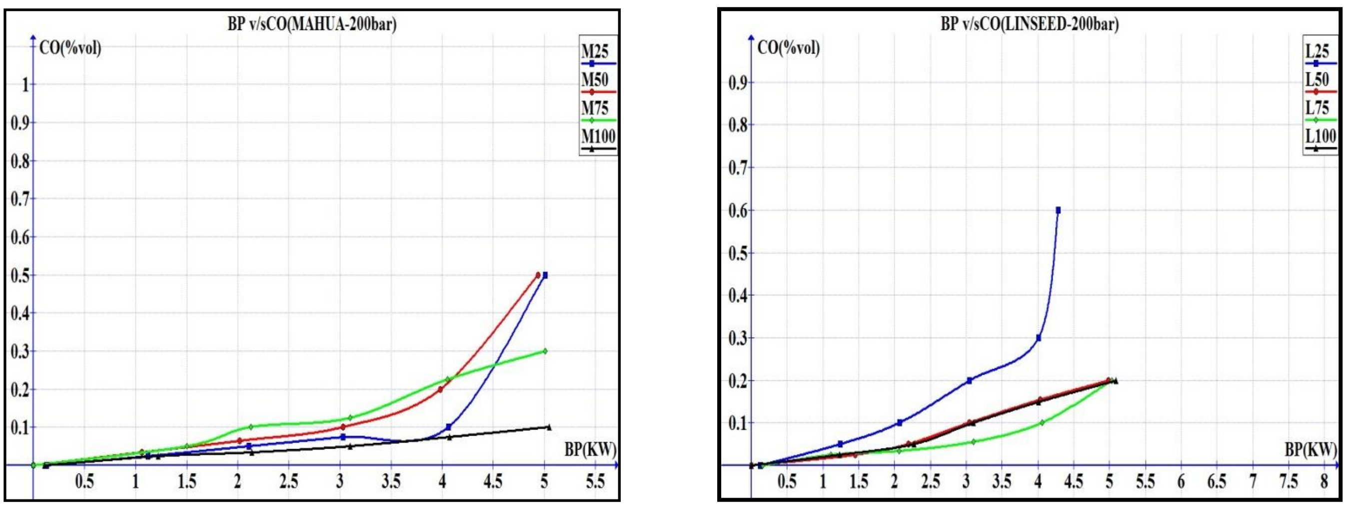

Figure 9 Comparison of CO between Mahua biodiesel blends and Linseed biodiesel blends at 200 bar injection pressure.

The effect of load on carbon monoxide (CO) emissions for diesel, Mahua biodiesel, and their blends is shown in Figure 9 Figure 10 and Figure 11. It can be seen from the figure that the higher CO emissions were obtained with Mahua biodiesel and its blends than Linseed biodiesel and its blends. The CO emission is 1.2, 0.6, 1.3 and 1.4% for Linseed biodiesel, L25, L50, L75 and L100 respectively, at 100% load and CO emissions is 0.6, 0.2, 0.3 and 0.2% for Mahua biodiesel M25, M50, M75, and M100 at 100%load. Higher CO emissions in the exhaust gas of the engine may be attributed due to the polymerization that takes place at the core of the spray, this also caused concentration of the spray core and decreased the penetration rate. Low volatility polymers affected the atomization process and mixing of air and fuel causing locally rich mixture, which leads to difficulty in atomization and vaporization of neat Mahua biodiesel due to improper spray pattern produced. This feature increases the incomplete combustion and hence higher CO emission.

2.2 *Unburnt Hydrocarbon emission*

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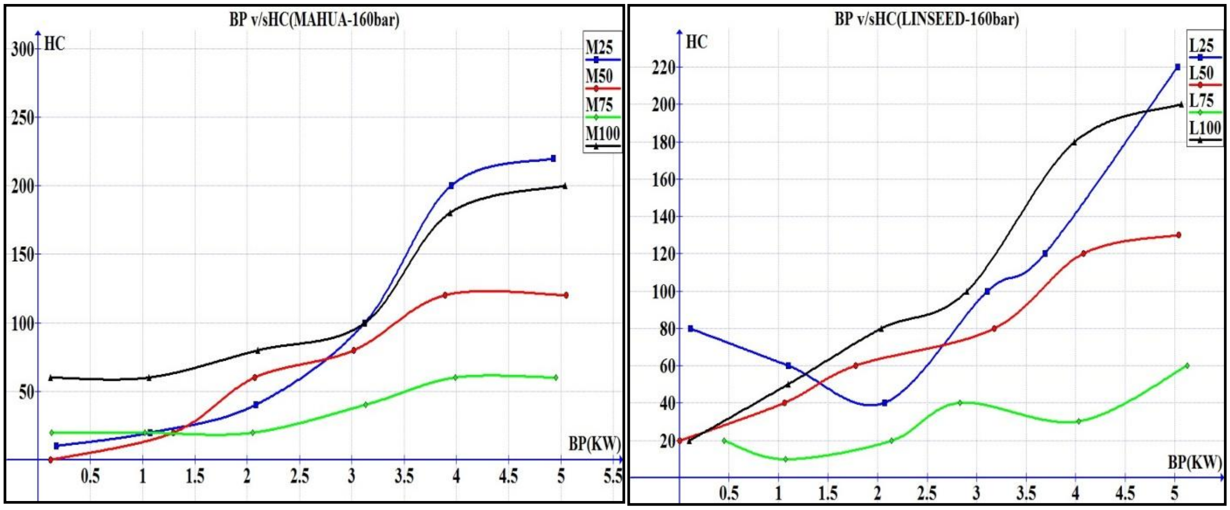

Figure 10 Comparison of HC between Mahua biodiesel blends and Linseed biodiesel blends at 160 bar injection pressure

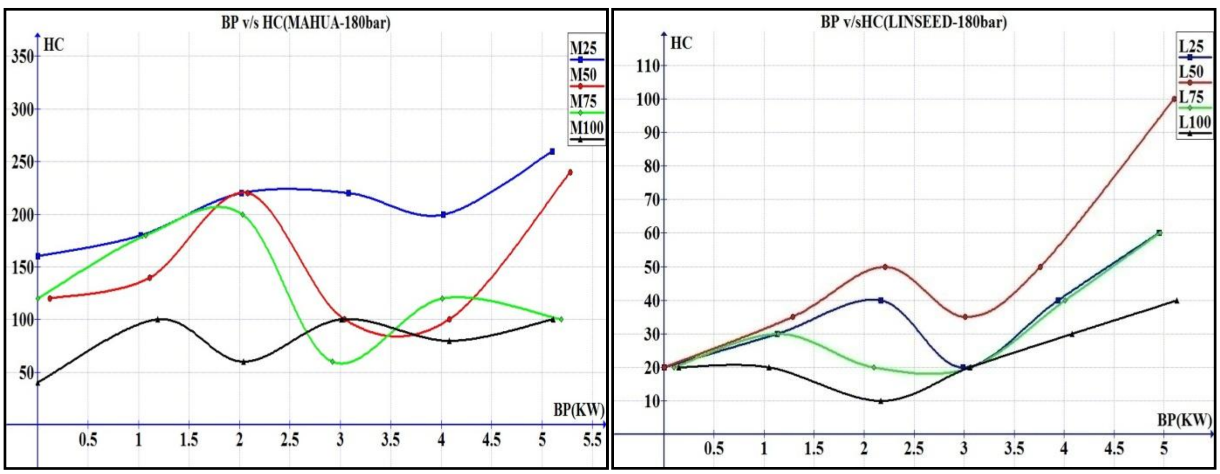

Figure 11 Comparison of HC between Mahua biodiesel blends and Linseed biodiesel blends at 180 bar injection pressure

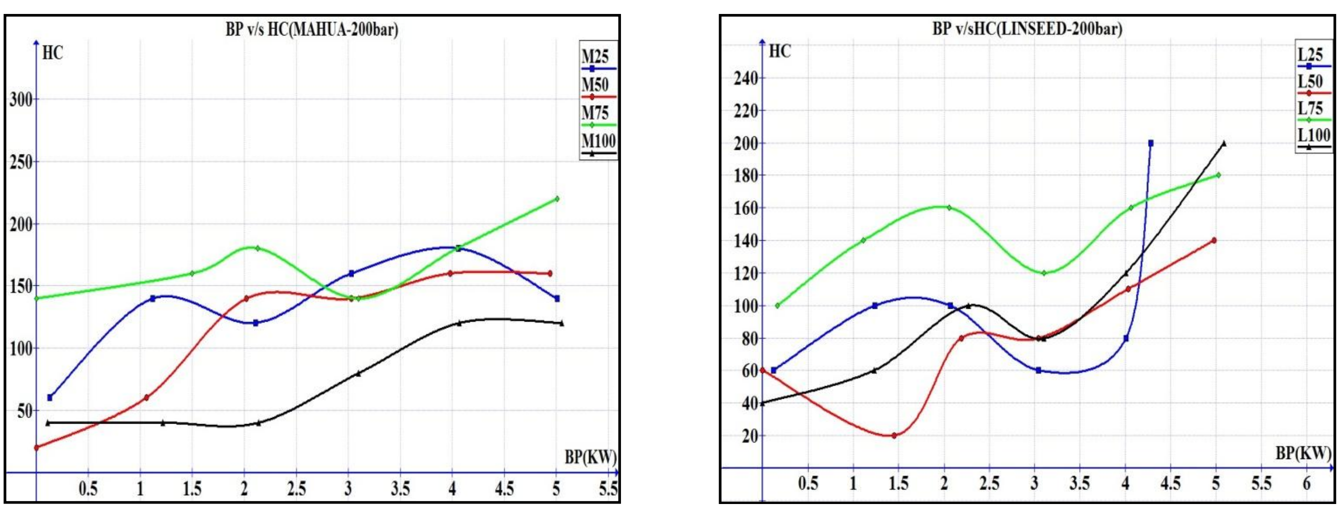

Figure 12 Comparison of HC between Mahua biodiesel blends and Linseed biodiesel blends at 200 bar injection pressure

The effect of load on unburned hydro-carbon (Hc) emissions for diesel, neat Mahua biodiesel and their blends is shown in Figure 12, Figure 13 and Figure14. It can be seen from the figure that the lower HC emissions were obtained with blends of Mahua biodiesel-diesel and neat Mahua biodiesel mode of operation for loads above 40% compared to Linseed biodiesel and its blends. The HC emission is 40, 20, 10, 20 ppm for Linseed biodiesel, L25, L50, L75 and L100 respectively, at 100% load and Hc emissions is 10, 0, 20, 60 ppm for Mahua biodiesel M25, M50, M75, and M100 at 100%load. Lower HC emissions in the exhaust gas of the engine may be attributed to the efficient combustion of Mahua biodiesel and blends due to the presence of fuel bound oxygen and warmed-up conditions at higher loads. Whereas at lower loads (up to 40%) higher Hc emissions were observed with blends of Mahua biodiesel-diesel and neat Mahua biodiesel operations. This is due to the reason that at lower loads the lower cylinder pressure and temperatures were experienced that was caused by lower rate of burning. This feature results in higher HC emissions.

CONCLUSION

The performance characteristics, brake thermal efficiency, brake specific fuel consumption, and emission characteristics, carbon monoxide, hydro-carbon of a single cylinder vertical direct injection Kirloskar engine using Mahua and Linseed biodiesels with their blends as fuels were experimentally investigated. The following conclusions are made based on the experimental results.

1. As the proportion of Mahua biodiesel increases in the blend, the brake thermal efficiency decreases. For M50, the brake thermal efficiency was 13.49% less than that of L50 at 160 bar pressure full load.
2. More the proportion of Mahua biodiesel in the blend more is the increase in brake specific fuel consumption for any given load.
3. The carbon monoxide emissions are more with Mahua biodiesel when compared to Linseed biodiesel at full load condition.
4. At 20% load, HC emissions for Mahua biodiesel and blends are quite high. At higher loads, as the quantity of Mahua biodiesel in the blend increases HC emissions decreases.

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