Performance and Emission Characteristics of Diesel Engine Using Lemongrass Oil, Jatropha Biodiesel and Diesel Oil Blends

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A b s t r a c t:

Due to the sudden rise in prices and increased awareness of the harmful effects of crude oil on the environment, biodiesel, considered an environmentally friendly source of energy, has become too important as an alternative fuel in recent years. Energy resource demand is rising at a very rapid rate and demand for liquid fuel in the transport sector is very high. Lemongrass oil *(Cymbopogon flexuosus)* and jatropha oil *(Jatropha curcas)* are used as an alternative fuel for the diesel engine in the present study. The performance, combustion and emission characteristics of a 4.4 kW, single-cylinder, four-stroke diesel engine, when fueled with Jatropha biodiesel, lemongrass oil and its 10-10%, 20-20%, 30-30%, 40-40%, 5-5%, 15-15%, 25-25%, 50-50%, 20-40%, 40-30%, 60-20% and 80-10% blends (on a volume basis) with diesel are investigated and compared with that of the standard diesel. Various experiments have been conducted at a fixed engine speed of 1500 rpm and at no load, 25%, 50%, 75%, and 100% load. The main study is conducted with the aim of increasing the different parameters and characteristics of engine performance by using different selected blends of jatropha biodiesel, lemongrass oil with diesel. The parameters of engine performance such as brake power, brake-specific fuel consumption, brake thermal efficiency, smoke density, absorption coefficient, and exhaust temperature were measured and the optimum blends that gave these parameters the best results were investigated. The diesel engine blends L30J30D40 and L40J40D20 is obtained as the best-blended fuel. The results of the experiment have been analyzed and compared with standard diesel. It is observed that there is a slight improvement in the combustion and emission characteristics of the engine by using some blends. It is also concluded that biodiesel and it's all blends show approximately similar properties to that of diesel fuel, thus they provided satisfactory results on the engine. The exhaust gas emissions of biodiesel and its all blended fuel types are also found better than that of diesel fuel except at 100% load. Therefore, all these blends can be effectively and efficiently used as an engine fuel without any modifications in the engine.

Keywords

Diesel engine Biodiesel Smoke density Performance Jatropha Lemongrass

1. Introduction

The inventory of diesel-based fuel is, directly and indirectly, depending on the increasing requirement for humans for energy productions, industries, vehicles, and equipment, etc. This reserve is a limited amount in the world and decreasing day by day. In this situation, the cost of diesel-based fuel is expected to hike in the following years. The use of diesel-based fuel is increasing exhaust gases in the environment which creates an adverse effect on climate as well as human health.

Resources of crude raw oil are limited, so it has become necessary to produce an alternatives source of origin for the planned future which is renewable and easily accessible. As the fossil oil is unrenewable and limited, its requirements and price both are continuously increasing. By using successive vegetable fuels in a diesel engine as a different alternative fuel, necessary modifications to the engines are required, which is costly. But by using biofuel, the problems of engine modification and specification can be easily solved. This research show biofuels as a resource for future renewable and biofuels.

Vegetable oil in CI engine and suggested that esters processed from vegetable fuel can be easily used as a biofuel in pure diesel engines, expected to better fuel properties like viscosity, volatility than triglycerides. They also have greater thermal performance related to diesel fuel. [14]

Nomenclature

L10J10D80	Fuel blend of Lemongrass oil 10%+ Jatropha biodiesel 10%+ Diesel fuel 80%	L20J60D20	Fuel blend of Lemongrass oil 20%+ Jatropha biodiesel 60%+ Diesel fuel 20%
L20J20D60	Fuel blend of Lemongrass oil 20%+ Jatropha biodiesel 20%+ Diesel fuel 60%	L30J40D30	Fuel blend of Lemongrass oil 30%+ Jatropha biodiesel 40%+ Diesel fuel 30%
L30J30D40	Fuel blend of Lemongrass oil 30%+ Jatropha biodiesel 30%+ Diesel fuel 40%	L40J20D40	Fuel blend of Lemongrass oil 40%+ Jatropha biodiesel 20%+ Diesel fuel 40%
L40J40D20	Fuel blend of Lemongrass oil 40%+ Jatropha biodiesel 40%+ Diesel fuel 20%	JOME	Jatropha oil methyl ester
		BSFC	Brake specific fuel consumption
L5J5D90	Fuel blend of Lemongrass oil 5%+ Jatropha biodiesel 5%+ Diesel fuel 90%	BP	Brake power
		DI	Direct injection
L15J15D70	Fuel blend of Lemongrass oil 15%+ Jatropha biodiesel 15%+ Diesel fuel 70%	CI	Compression ignition
		BTE	Brake thermal efficiency
L25J25D50	Fuel blend of Lemongrass oil 25%+ Jatropha biodiesel 25%+ Diesel fuel 50%	EGT	Exhaust gas temperature
		FTIR	Fourier transform infrared spectroscopy
L50J50D00	Fuel blend of Lemongrass oil 50%+ Jatropha biodiesel 50%+ Diesel fuel 00%	D	Diesel
		ppm	parts per million
L10J80D10	Fuel blend of Lemongrass oil 10%+ Jatropha biodiesel 80%+ Diesel fuel 10%	GHG	Green House Gases
		LGO	Lemongrass oil

Studied four different ways of biofuels generation such as blend, micro-emulsion, dullness, and trans-esterification in which the trans-esterification reactions are the most regularly used methods of biofuel generation. The trans-esterification reaction is stirred by so many factors like the type of catalysts used, reaction temperature or time, the molars ratio of alcohol to glycerol, free fatty acid and water contents of biofuel. [7]

Proved that biodiesel can be simply replaced with diesel as an alternative biofuel in the aspect of its various unique properties such as non-sulfur emission, low toxicity, biodegradability and the significant supply of cut in GHG emission. [11]

Lemongrass *(Cymbopogon flexuosus)* is a grass family member containing 1 to 2 percent dry-based essential oil. Lemongrass oil has a lemony, sweet smell and a dark yellow color to amber and reddish with a watery viscosity. Cymbopogon citral or citral is the main component of lemongrass oil. Lemongrass oil is 65% to 85% citric. Citral is a pale yellow liquid with a strong fresh lemon smell that is often colourless. The process of steam distillation extracts it from fresh leaves.

The fresh oil of LGO was collected through the steam purification process. LGO biofuel blend with diesel oil in the different amount on quantity basis 10%, 30%, 20%, 40%, & 100%. Among the different blends, the L20-D80 blend declares a 6% drop in efficiency and 9% drop higher fuel consumption and full load commonly as correlated with pure diesel fuel. [8]

On a quantity basis, 20 percent raw lemongrass oil was blended with diesel, and a different percentage of CO_2 nanoparticles, namely L20-D80+10 ppm, L20-D80+20 ppm, and L20-D80+30 ppm were prepared. NOx and exhaust emission were together decreased by 3% and 6.6% commonly as related to biofuel diesel blend. The experiential study discovers that the using of nanoparticles results in greater thermal efficiency and decreased unsafe emissions. 20 ppm cerium nanoparticles keep achieving a greater brake thermal performance of 4.76% unsettled to its oxygen buffer tendency. [5]

Fig 1 (a): Lemongrass tress **Fig 1 (b):** Lemongrass root

Fig. 1: Lemongrass tree and root [22]

Jatropha curcas contains fatty acids that are suitable for the production of biofuels. The plant may grow in India arid, semi-arid conditions and wastelands (excluding saline or alkaline wastelands). The plant needs a small-scale amount of fertilizer and water (about 50 liters per plant), according to Forbes India. The plant is not browsed by bovine animals and is also resistant to pests. It has a high seed yield that for 30-40 years continues to be produced. Jatropha seed oil content is around 30-40%. Forbes also points out that jatropha's crop yield is about 2 tons per hectare. In India, there are approximately 65 million hectares of wasteland that can be used to grow jatropha.

Fig 2 (a): Jatropha trees

Fig 2 (b): Jatropha seeds

Fig. 2: Jatropha trees and seeds [10]

The properties of jatropha biofuel blends in diesel fuel have been studied. The study showing that an important reduction in viscosity of vegetable oil occurs with diesel addition in varying amounts. The fuel blends consist of up to 30.0% JOME by volume have viscosity value near related to neat diesel oil. Blend with 40% vegetable oil by volume reported viscosity marginally higher than neat diesel fuels. The viscosity of blends further decreased with heating. Lower percentages of vegetable fuel reported a slight increase in EGT in comparison to the engines running with diesel fuel. [15]

Performed experiment biodiesel is a methyl or ethyl ester of fatty acids made from vegetable oils (both edible and non-edible) and animal fat. Non-edible oil obtain from plant species like Jatropha curcas, Pongamia pinnata, Hevea brasiliensis, and Calophyllum inophyllum maybe the main resources for biodiesel production. Biodiesel can be used pure or mixed with diesel to form various blends. It can be used with very few or no engine modifications in CI engine. All esters result in smoke emissions that are slightly higher than diesel. All the esters tested to lead to slightly lower thermal efficiency and increased levels of smoke, CO and HC. The existing engine could be operated on the test esters without any major modifications. [3]

The brake specific fuel consumption of JOME or it blends fuels with diesel continue higher than diesel fuel and brake thermal energy was found to be decreased. However, NOx emission on JOME or it blends fuel to continue greater than diesel. HC, CO along with CO_2 and smoke continue found to be lower with JOME. After the transesterification process of JOME, its kinematic viscosity at 40°C and specific gravity get decreased. The jatropha biofuels from jatropha oil have greater density but decreased calorific value than that of diesel. [4]

Dual biofuel blends, a mixture of two different biofuel types namely palm oil and jatropha oil in diesel was considered for opinion in a single-cylinder DI diesel engine with varying loads after physical property analysis. Results for lower biofuel blend D90PB5JB5 (i.e. 90 percent diesel & 10 percent biodiesel) with diesel showed an average brake power increase of 4.65 percent compared to diesel. BSFC lower blends have seen a slight decrease. Higher biofuel blend D20JB40PB40 (i.e. 20 percent diesel & 80 percent biofuel) showed an average thermal brake efficiency increase of up to 15 percent. For most biofuel blends, a noticed decrease in EGT was observed. [13]

2. Materials and Methods

2.1 Biodiesel production

Lemongrass oil was purchased from a local Pantnagar distributor and jatropha oil was purchased from Sinhal Herb's distributor Neemuch M.P. jatropha oil biodiesel or jatropha oil methyl ester (JOME) was prepared through the process of esterification and transesterification reaction. In an IC engine Laboratory, Department of Mechanical Engineering, College of Technology, Pantnagar. Jatropha oil is first converted to biodiesel using reaction esterification and transesterification to enhance its different properties. In the presence of H_2SO_4 (1%) and KOH (1% by weight) as a catalyst, methanol (13% by weight) is used as alcohol. Using esterification and transesterification reactions, 94% of biodiesel yield is obtained.

Transesterification reactions 250 ml oil was filtered and its weight was measured before being poured into the conical flask. The esterification process reduces the amount of impurities in the oil. In this, 1% w/w H_2SO_4 is used and mixed with 13% w/w Methanol and heated up to 50°C. Jatropha oil is added to this mixture and the mixture is heated and stirred for 90 minutes at 300-400 rpm. This solution is then transferred to a separation funnel and permitted for 24 hours to settle. The tri-glyceride is a reaction with alcohol during the esterification reaction in the presence of a catalyst, mostly a strongly alkaline such as KOH. In this process, the product of esterification is further treated with Methanol in the presence of a base as KOH. The alcohol is heated with the base at 50°C and added to the products of esterification and heated to 50°C with constant stirring at 300-400 rpm for 120 minutes and the product is then let to settle for 24 hrs. The impurities settle at the base of the separating funnel as shown in fig. 4.

Fig. 3: Process of Esterification

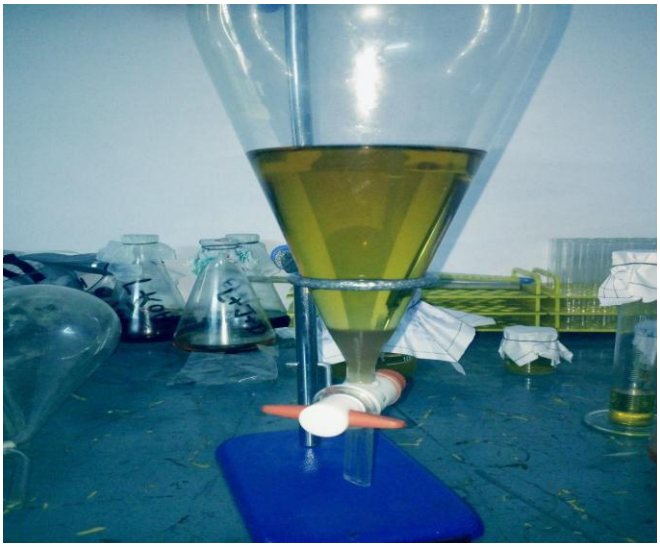

Fig. 4: After transesterification, biodiesel floated in the funnel separation

2.2 FTIR spectroscopy for JOME and Lemongrass oil

FTIR was done in the laboratory department of environmental science, College of Basic Science and Humanities, Pantnagar. FTIR experiment of the jatropha oil methyl ester, lemongrass oil, jatropha pure oil, and diesel was analyzed and they were recorded with instrument FTIR-BRUKER-ALPHA 200 model USA.

The lemongrass oil FTIR, which identifies different functional characteristic groups present in the blends. The chemical bonding will stretch, contract and absorb infrared radiation within a specific range of wavelengths during the infrared light interaction with the fuel. FTIR-BRUKER-ALPHA 200 United States model. For recording the FTIR spectroscopy of the given oil sample was used. It has bands of absorption of 4000-400 cm^{-1}. OH group peak absorption showed that phenolic compounds appeared at 2924 cm^{-1} frequency.

Transmittance versus wavenumber variation of jatropha oil methyl ester, lemongrass oil, jatropha pure oil, and diesel has been plotted in fig.4 and fig.5 represents notable differences in wavenumbers of lemongrass oil and diesel fuel which is due to the presence of OH groups in biodiesel. The OH groups are described in biodiesel.

2.3 Biodiesel preparation

Fuel blends of jatropha oil methyl ester, lemongrass oil, and diesel prepared in different selected percentages and terminology used in the present study. It was observed that fuel blends get a light color by adding lemongrass oil in excess amounts. In the initial stage of work, the fuel blends were kept in the room temperature 30°C for 24 hours for testing of miscibility and stability. Then all the properties of different fuel blends like calorific value, kinematic viscosity, relative density, flash point, fire point, cloud point and pour point are measured and plotted. All the properties determined according to Bureau of Indian standards. The prepared blends were L10J10D80, L20J20D60, L30J30D40, L40J40D20, L5J5D90, L15J15D70, L25J25D50, L50J50D00, L10J80D10, L20J60D20, L30J40D30 and L40J20D40.

2.4 Measurement of fuel properties

2.4.1 Viscosity, density and calorific value of fuels

For selected fuels, important fuel properties such as relative density, kinematic viscosity, gross calorific value, are determined. Fuel blends properties are measured in the IC engine lab of the mechanical engineering department according to the Bureau of Indian Standards, New Delhi and Institute of Petroleum, London. The following apparatus is used to measure the properties of fuel blends as well as diesel.

2.5 Experimental setup and testing

The engine test set up available in the Internal Combustion Engine Laboratory of the Department of Mechanical engineering was used. The setup includes the following facilities:

An eddy current dynamometer with electronic controller, A Kirloskar 4.4 kW constant speed of engine as shown in **fig. 8**, A separate fuel consumption measuring unit, K-type thermocouple wire with scanner logger temperature, Smoke meter setup and tachometer. The engine is commonly used in agriculture operations such as irrigation pumps, milling and stationary power source for different field operations likewise a prime mover in electric generators for household usage. The major specifications of the engine are shown in **Table 1.**

3. Results and discussions

3.1. Measurement of fuel property

The relative density of diesel was measured as 0.845 in the present work. Relative density for jatropha oil methyl ester and lemongrass oil were found 0.860 and 0.920

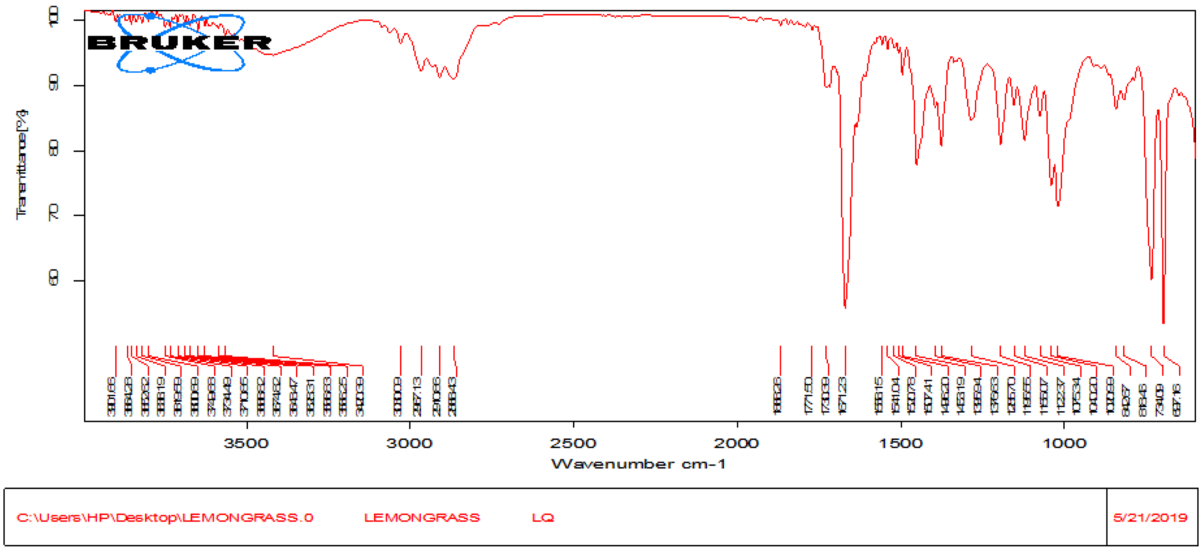

Fig. 5: Fourier transforms infrared spectroscopy of lemongrass oil

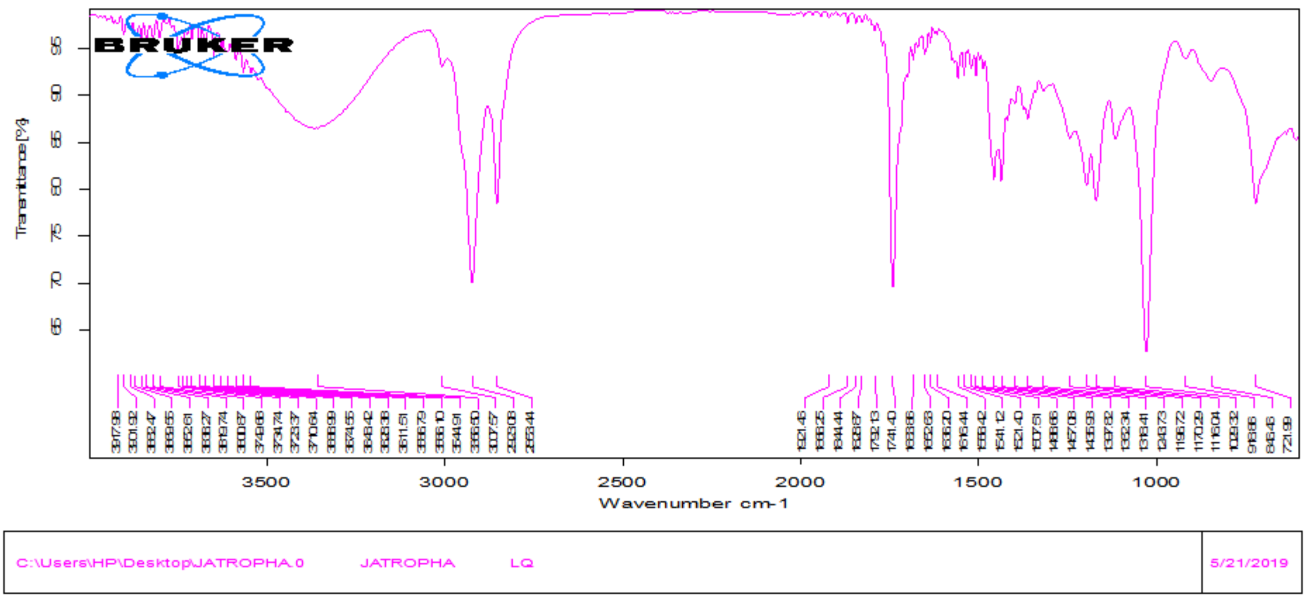

Fig. 6: Fourier transform infrared spectroscopy of jatropha oil methyl ester

respectively in the present investigation. According to **[13]** reported relative density of jatropha oil methyl ester and diesel at 0.8649 and 0.8269 respectively. **[5]** Stated the value of relative density for lemongrass oil as 0.905.

The kinematic viscosity of diesel, jatropha oil methyl ester, lemongrass oil, and their blends was determined with the help of Redwood viscometer at 40°C. The kinematic viscosity of diesel was found to be 2.945 cSt. **[9]** Observed its value as 2.95 cSt at 40°C, though **[20]** reported that kinematic viscosity of diesel is 3.25 cSt at 40°C. **[21]** Has stated that the kinematic viscosity of diesel fuel at 40°C is 2.37 cSt. Kinematic viscosity of jatropha oil methyl ester (JOME100) was found to be 4.85 cSt at 40°C. **[13]** Experimental results jatropha oil methyl ester (JOME100) obtained showed its value as 5.48 cSt. Kinematic viscosity of lemongrass oil was found be the lowest among them compared to JOME100 i.e. 3.400 cSt. **[5]** Reported it as 4.6 cSt at 40°C. JOME was found to be 4.85 cSt at 40°C in the current study. The gross calorific value of different blends. It is observed heat of the combustion value of diesel is 44.12 MJ/kg, the heat of biodiesel (JOME100) 38.90 MJ/kg and heat of lemongrass oil 36.80 MJ/kg. Biodiesel's calorific value and blends are lower than diesel. **[5]** Found the calorific value of diesel and lemongrass oil is 44.12 MJ/kg and 37.00 MJ/kg respectively. **[13]** Found the

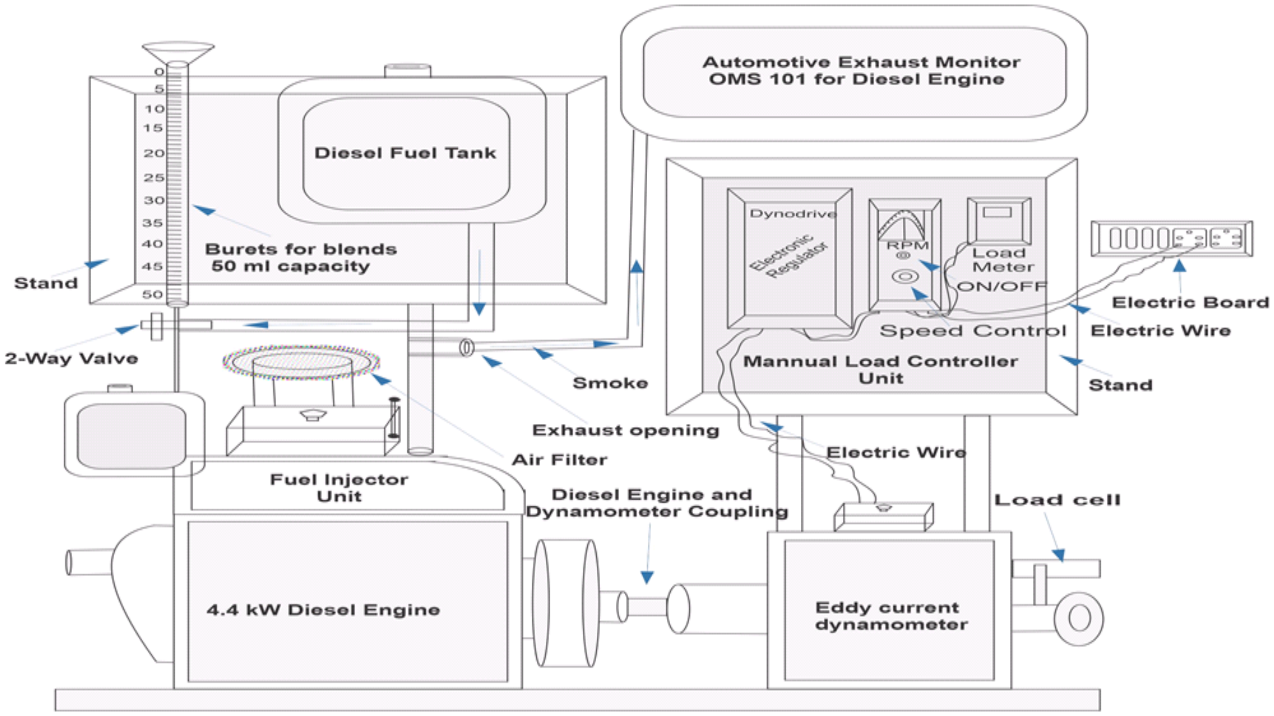

Fig 7: Schematic diagram of the diesel engine with eddy current dynamometer

calorific value of jatropha oil methyl ester is 39.847 MJ/kg. **[4]** Found the calorific value of diesel and jatropha oil methyl ester is 43.00 MJ/kg and 38.450 MJ/kg respectively. The measured fuel properties are shown in **Table 2.**

3.3. Thermal stability

The stability of blends was studied by observing phase separation at room temperature after 24 hours of their preparation. A total of twelve blends were prepared for diesel-lemongrass-jatropha and it was found that all the twelve blends were stable and showed no phase separation after a period of 24 hours at room temperature which varied from 25°C to 30°C. Even after thirty days, they are in clear from and stable state.

Table 1. Engine specification

Parameters	Specifications
Made	Kirloskar
Model	TAFI
Rated BP (bhp/kW)	6/4.4
Rated Speed (rpm)	1500
Number of Cylinder	1
Bore x Stroke (mm)	87.5 x 110
Displacement volume (cc)	662
Compression Ratio	17.5:1
Cooling System	Air Cooled
Lubricating System	Forced Feed
Starting System	Manual hand start (with handle)

Table 2. Measured fuel properties of all fuel blends

Fuel Blends	Kinematic Viscosity (cSt)	Relative Density (g/ml)	Calorific Value (MJ/kg)
Diesel	2.945	0.845	44.12
L10J10D80	2.805	0.838	43.08
L20J20D60	3.097	0.854	41.81
L30J30D40	3.389	0.870	40.54
L40J40D20	3.682	0.883	39.27
L5J5D90	2.980	0.839	42.190
L15J15D70	3.140	0.836	40.237
L25J25D50	3.222	0.846	39.386
L50J50D00	3.980	0.875	37.44
L40J20D40	3.215	0.878	40.40
L30J40D30	3.624	0.874	39.97
L20J60D20	4.032	0.871	39.55
L10J80D10	4.441	0.866	39.12
JOME100	4.85	0.860	38.90
L100	3.400	0.920	36.80

3.4. Performance Characteristics

3.4.1 Brake Power (BP)

The output power of an engine is known as brake power. The fig. 8 indicates an increase in brake power with an increase in break load of the engine under all fuel types. The figure also reveals that with increase in brake load there was an increase in brake power and decrease in engine speed on all the jatropha oil methyl ester, lemongrass oil, and diesel blends. It was observed that the engine was able to develop similar power on all fuel types at every selected brake load condition. This could be due to the reason that the volumetric fuel flow rate on biodiesel was higher thus contributing energy supply near diesel. Generally, the brake power obtained from experiments was approximately similar at any load for diesel and blends of jatropha oil methyl ester, lemongrass oil, and diesel. This happened due to the higher fuel consumption of blends due to its lower calorific value as compared to diesel to carry the same load which resulted in the same brake power of the engine at any load for all fuel blends and diesel. The brake power will be minimum at 25% load for all fuel blends and maximum at 100% load. The maximum value of brake power will obtain at 100% load for L20J20D60 blend.

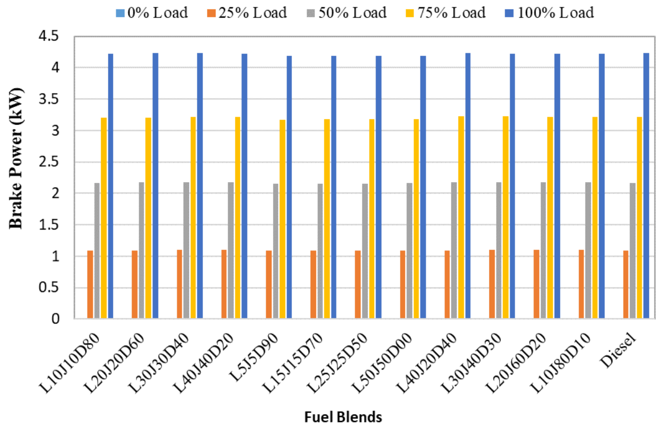

Fig. 8: Brake power of all selected fuel blends

3.4.2 Fuel consumption

Fig. 9 shows the variation in fuel consumption for all blends at all selected loads. From the figure, the fuel consumption of the diesel is found to be minimum at all loads expect at 25% load at approximately equal at 30% load. At 25% load condition, L20J20D60 blends show the minimum value of fuel consumption of 0.645 l/hr which is 2.12% lower than the value of diesel. The fuel consumption of L20J20D60 at 25% is minimum may be due to its high cetane no. which increases the ignition quality of the fuel. The maximum value of fuel consumption is obtained for the L15J15D70 blend which is 1.848 l/hr at full load 100% condition. The fuel consumption of pure biodiesel is lower than the diesel for all loading conditions this may be due to its lower heating value, high viscosity and low volatility. These properties decrease the consumption of fuel. As the load increases fuel consumption increase for all loading conditions because for producing high power more fuel is injected in the diesel engine.

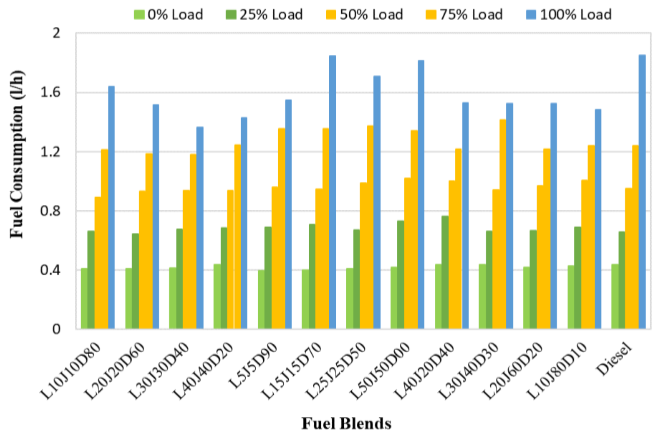

Fig. 9: Fuel consumption of all selected fuel blends

3.4.3 Brake specific fuel consumption

It is noticed that the brake specific fuel consumption of engine decreases with increases in load for all fuel types due to higher brake power at higher load. At full load condition brake specific fuel consumption of diesel was found to be 0.369 kg/kW-h.

It is observed that brake specific fuel consumption of the engine for all selected test fuels at 100% load condition was found to be 0.369, 0.326, 0.305, 0.281, 0.299, 0.311, 0.369, 0.346, 0.379, 0.318, 0.315, 0.314, 0.305 on diesel, L10J10D80, L20J20D60, L30J30D40, L40J40D20, L5J5D90, L15J15D70, L25J25D50, L50J50D00, L40J20D40, L30J40D30, L20J60D20, L10J80D10.

In the case of jatropha oil methyl ester, lemongrass oil and diesel blends minimum and maximum brake specific fuel consumption are noticed for L30J30D40 and L50J50D00 respectively at full load as shown in fig. 10(a), fig. 10(b), fig. 10(c) and fig. 11. It is observed that increasing the percentage of jatropha oil methyl ester, lemongrass oil in diesel decreases the brake specific fuel consumption of the engine and this may be because of better combustion of fuel due to oxygen present in jatropha oil methyl ester, lemongrass oil.

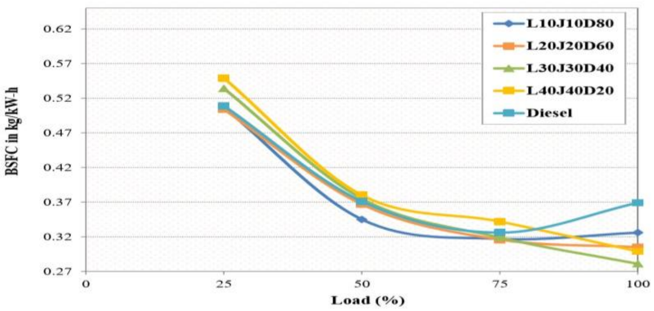

Fig. 10 (a): Load v/s brake specific fuel consumption of L10J10D80, L20J20D60, L30J30D40, L40J40D20, and diesel

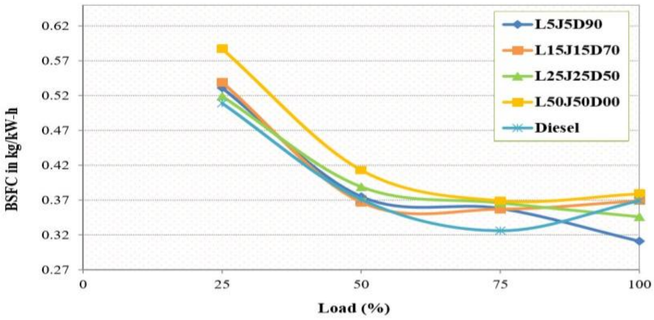

Fig. 10 (b): Load v/s brake specific fuel consumption of L5J5D90, L15J15D70, L25J25D50, L50J50D00, and diesel

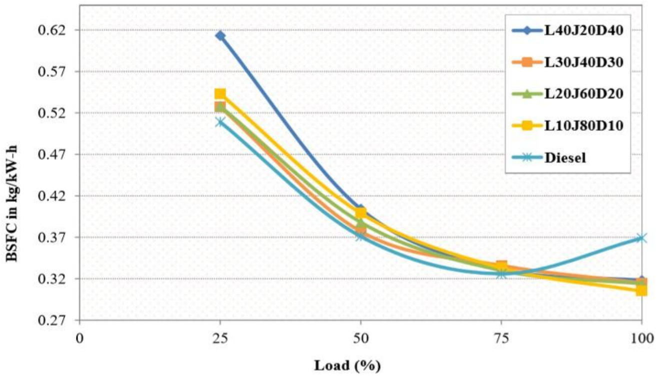

Fig. 10 (c): Load v/s brake specific fuel consumption of L40J20D40, L30J40D30, L20J60D20, L10J80D10, and diesel

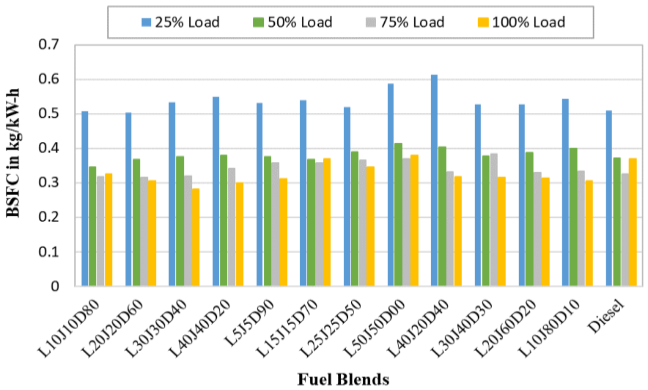

Fig. 11: Brake specific fuel consumption of all selected fuel blends

3.4.4 Brake thermal efficiency

Fig. 12(a), fig. 12(b), fig. 12)c) and fig. 13 shows the comparison of brake thermal efficiency (BTE) versus load (%) for all different test fuels. The addition of jatropha oil methyl ester, lemongrass oil and diesel reduces the viscosity of the fuel, increases volatility and the inherent oxygen in jatropha oil methyl ester and lemongrass oil improves the combustion phenomenon. Jatropha oil methyl ester, lemongrass oil and diesel addition in 30-30-40% biodiesel (J30L30D80) show higher brake thermal efficiency as compared to diesel. But the further increase of percentage of jatropha oil methyl ester and lemongrass oil in blend reduces the calorific value of fuel which intakes more amount of fuel to develop the same power, and hence the brake thermal efficiency for L40J20D40 was reduced at 25%. The highest brake thermal efficiency was 33.44% at 100% load for L30J30D40 increased by 27.90% with respect to diesel as shown in Fig. 12(a).

The other reason for the high thermal efficiency of biodiesel is oxygenated molecules as in lemongrass oil, which is present in biodiesel. That excess amount of these oxygenated molecules in biodiesel provides complete combustion of fuel, which in turn results in its maximum efficiency than diesel fuel.

The brake thermal efficiency of biodiesel is found maximum at 100% load which is equal to 33.44%. The brake thermal efficiency value diesel at 100% load is 24.11% which is 27.90% lower than biodiesel.

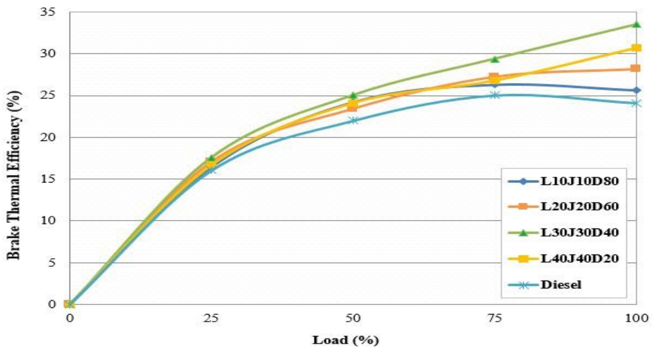

Fig. 12 (a): Load v/s brake thermal efficiency of L10J10D80, L20J20D60, L30J30D40, L40J40D20, and diesel

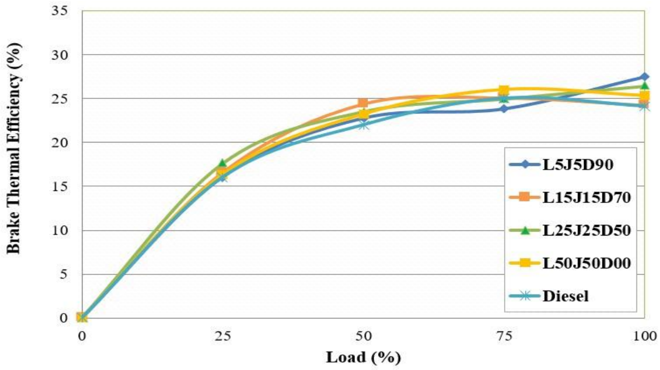

Fig. 12 (b): Load v/s brake thermal efficiency of L5J5D90, L15J15D70, L25J25D50, L50J50D00, and diesel

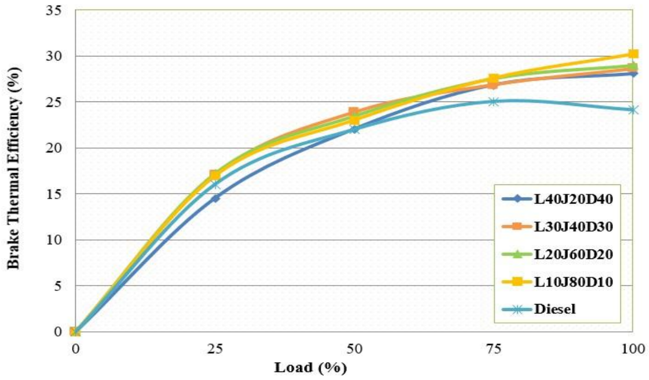

Fig. 12 (c): Load v/s brake thermal efficiency of L40J20D40, L30J40D30, L20J60D20, L10J80D10, and diesel

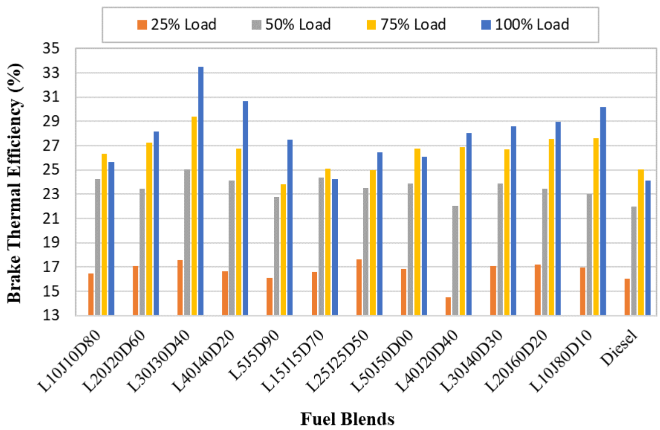

Fig. 13: Brake thermal efficiency of all selected fuel blends

3.4.5 Smoke density

The smoke density characteristics for diesel is the least and highest in the case of biodiesel blends. This is because of lower viscosity and higher volatility, which helps in good mixture formation for the complete combustion that takes place for diesel and due to higher viscosity and higher volatility, which results in improper atomization in the case of neat biodiesel. While in case of micro-emulsions the smoke density is found lower as compared to biodiesel due to lower viscosity and higher volatility due to the presence of alcohol which results in proper atomization of fuels. A comparison of the smoke opacity characteristics for different fuel is shown in fig. 14. It is observed that the smoke density increase with increase in brake load. Shows the graphical representation of smoke emission of selected fuel blends against different brake loads. It can be seen that smoke density is decreased with addition of JOME and lemongrass oil. In present study L40J20D40 gives minimum smoke density at full load for ternary blend. At full load, maximum value of smoke density is obtained for L50J50D00 blend which is found higher than diesel.

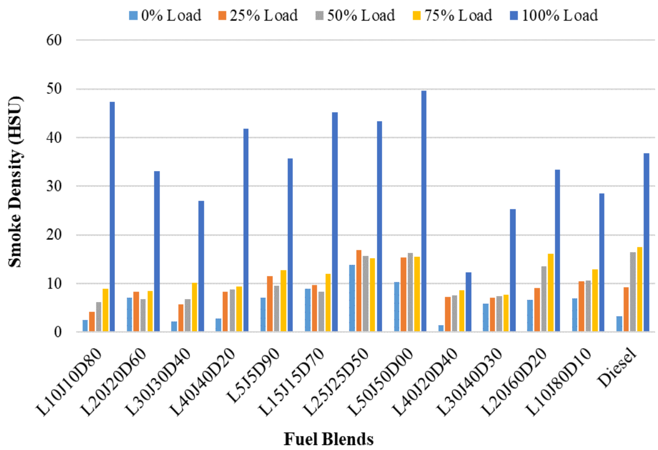

Fig. 14: Smoke density of all selected fuel blends

3.4.6. Exhaust gas temperature

Fig. 15 shows the variation in exhaust gas temperature for various test fuels versus load (%). As the percentage of load increases for all the tested fuels, the exhaust gas temperature (EGT) increases. This increase in EGT was due to the fact that in order to develop more power, an extra amount of fuel is required at higher load.

The exhaust gas temperature for Diesel, L10J10D80, L20J20D60, L30J30D40, L40J40D20, L5J5D90, L15J15D70, L25J25D50, L50J50D00, L40J20D40, L30J40D30, L20J60D20, and L10J80D10 was 190°C, 194°C, 191°C, 188°C, 195°C, 191°C, 219°C, 190°C, 207°C, 164°C, 177°C, 179°C and 180°C at full load. However blending with JOME, lemongrass oil for 40% and 20% biodiesel (L40J20D40) showed the highest reduction in exhaust gas temperature as compared to diesel at full load.

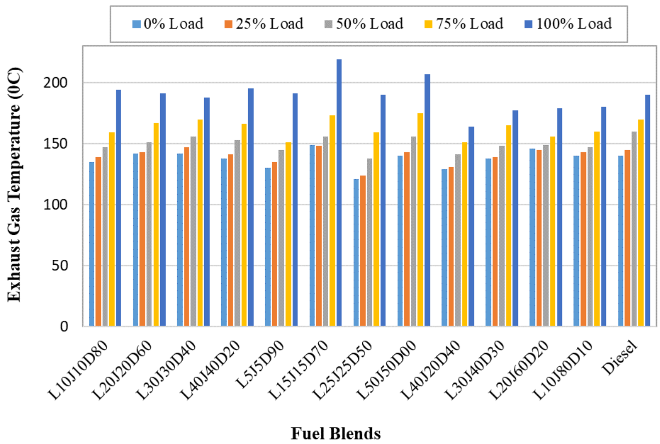

Fig. 15: Exhaust gas temperature of all selected fuel blends

4. Conclusions

The experimental studies were concluded using diesel-jatropha oil methyl ester biodiesel and lemongrass oil blends to achieve optimum results. Biodiesel extraction from jatropha raw oil was carried out successfully using a two-step esterification process using 1% (w/w) H_2SO_4 as an acid catalyst, 19% (w/w) methanol and heated up to 55°C in the first step esterification process and 1% (w/w) KOH as a base catalyst, 19% methanol and heated up to 55°C in the second step transesterification process with an yield of 94% biodiesel.

1. With the increasing percentage of lemongrass oil, the relative density of test fuels was found to be increased, while the API gravity decreases with the addition of lemongrass oil. The relative density of diesel, jatropha oil methyl ester and lemongrass oil respectively were found to be 0.845, 0.860 and 0.920.
2. JOME and lemongrass oil gross combustion value continue lower than diesel fuel. The gross combustion value of 38.90 MJ/kg and 36.80 MJ/kg respectively for JOME100 and L100. Which is 11.83% lower than diesel fuel and 16.59% lower. With the increasing proportion of lemongrass oil, the gross combustion value of various fuel blends was found to decrease. Due to lemongrass oil high density, more fuel will be consumed.
3. Under the engine fuel consumption test using selected fuel blends of jatropha oil methyl ester, lemongrass oil, and diesel oil. The engine performance was found satisfactory. Using all fuel blends, fuel consumption was lower than diesel.
4. Brake power of diesel engines on selected fuel blends was found to be similar and close to diesel.
5. The BSFC value of diesel and biodiesel was approximately similar. The maximum value of BSFC was 0.369 kg/kW-h for diesel at 100% load and maximum value for blends L50J50D00 at 100% load, which was equal to 0.379 kg/kW-h.
6. The BSFC value of diesel and biodiesel was approximately similar. The maximum value of BSFC was 0.369 kg/kW-h for diesel at 100% load and maximum value for blends L50J50D00 at 100% load, which was equal to 0.379 kg/kW-h.
7. With the increase in load, EGT may be increased for all types of fuel due to increased cylinder pressure due to fuel combustion improvement in the warmed-up condition.
8. Biodiesel smoke density and blends were found to be lower than diesel at 100% load for all load conditions expected. The diesel smoke density is at least 100% load than biodiesel and its blends. L40J20D40 blend smoke density was found to be at least 100% loads at all loads expected. The minimum smoke density value for L40J20D40 was 12.23 HSU at 100% load, which at the same load was 66.43% lower than diesel. For the L50J50D00 blend, which was 25.90% higher than diesel, it is the maximum value was 49.57 HSU at 100 percent. Although the smoke density was lower than that of diesel for some blends. At higher load, the percentage increase in smoke density was much higher than lower loads.

The above discussions show that the behavior of JOME and lemongrass oil was very influential. Even a 40% addition of JOME and lemongrass oil, improves the properties as well as emission characteristics of fuel. But in the present investigation where 30% was added in JOME and lemongrass oil blends improve the efficiency and smoke emission comparable to diesel. It is observed that, decrease the smoke density of fuel at full load condition. Although brake power, fuel consumption, thermal brake efficiency, and brake specific fuel consumption were found to be comparable to diesel.

All the above-mentioned blends can be recommended without modification of the engine as an engine fuel. However, it is found from the current investigation that optimum results are obtained by adding jatropha oil methyl ester, lemongrass oil, and diesel blends.

Therefore, fuel blends L30J30D40 and L40J40D20 can be recommended without engine modification as a diesel engine fuel with better performance and emission characteristics.

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