RESEARCH PAPER

EXPERIMENTAL EXPLORATION OF ENGINE PERFORMANCE USING LEAN SAPINDUS MUKOROSSI BIO-DIESEL BLENDED WITH PETRO-DIESEL AS ENGINE FUELS

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ABSTRACT - *In India's energy scenario, crude oil plays a pivotal role, as for being the leading consumed and imported product of the energy sector. Being a developing economy, India is thus faced with the dual task of meeting energy demand, as well as to curtail foreign expenditure on crude oil imports. However, substituting alternate fuels for petro-diesel can greatly assist in India's chore, as petro-diesel is the principal consumed product among the crude oil by-products.*

For the reason, in the present work, engine performance parameters of a single cylinder four stroke diesel engine were experimentally investigated using petro-diesel and lean soap nut (Sapindus Mukorossi) bio-diesel blends with petro-diesel as engine fuels. The results were analyzed and compared for petro-diesel and the blends, thus validating the use of lean soap nut bio-diesel blends as alternate fuels for diesel engine. Moreover, the best feasible lean soap nut bio-diesel blend was also suggested to cur tail foreign expenditure, decrease dependency on fast depleting fossil fuels reserves and meet the environmental concerns.

Keywords: Alternate Fuels, Bio-diesel, Soap nut Bio-diesel, Engine Performance Parameters.

1. INTRODUCTION

Today, India stands fifth in the world, both in terms of primary energy's demand and consumption. India's primary energy demand is 5.5% (770 Mt) of the World's primary energy demand (14000 Mt), and is expected to Grow at a rate of 6.8%. Whereas, India's primary energy consumption is 4.8% (576 Mt) of the World's primary energy consumption (12000 Mt), and is expected to grow at a rate of 6.2%.[1]

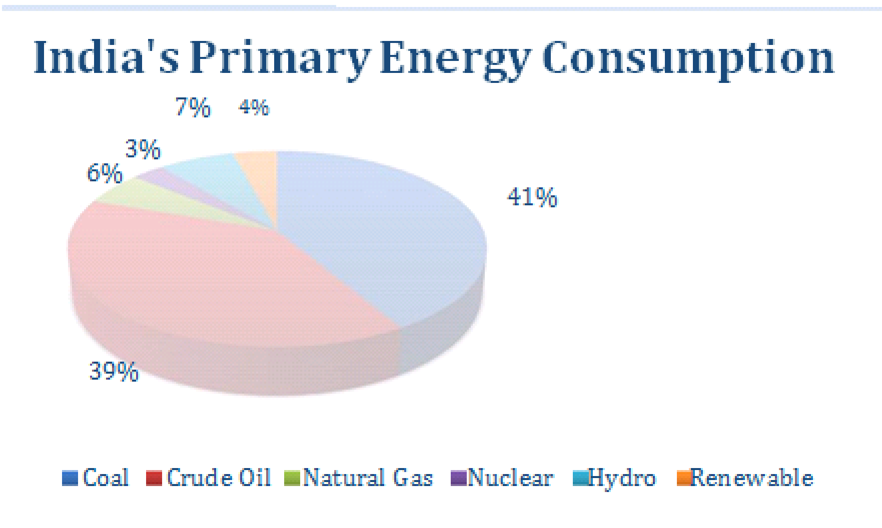

Fig. 1.1 India's Primary Energy Consumption

Fig. 1.1 shows percentage contribution of primary energy sources in India's Primary energy consumption. Of all the primary energy consumption, fossil fuels (crude oil (Petroleum) and natural gas) constitute 45% share. It is projected that, even if hydropower potential is exploited to the fullest, even if there is a 40 times increase in the contribution of renewable sources and a 20 times increase in the contribution of nuclear power capacity, by the year 2031-32, fossil fuels will continue to occupy a significant share in the primary energy consumption of India.[2] Moreover, among the fossil fuels consumption, crude oil constitute 87.5% share, whereas, natural gas constitute only 12.5%. Thus, crude oil plays a pivotal role in India's energy scenario.

During the decade 2005-2014, India's crude oil consumption increased from 130.11 MMTs during 2005-06 to 222.50 MMTs during 2013-14, with CAGR of 6.14%. On the other hand, production of crude oil increased only from 32.19 MMTs during 2005-06 to 37.79 MMTs during 2013-14, with CAGR of 1.80. As a result, India's expenditure on crude oil import increased from $37,610 million in 2005-06 to $1, 42,962 million in 2013-14, so as to meet our consumption requirements.[3, 4]

Crude oil or petroleum is refined to obtain many products e.g. petrol, diesel (Petro-diesel), LPG, kerosene, lubricants, fuel oils etc., which are used to meet our energy needs, as well as to carry out certain other operations. Of all the petroleum products, petro-diesel accounts for the highest consumption, with its share increasing from 32.85% in 2005-06 to 38.83% in 2013-14, with CAGR of 6.08%.[5] Hence, substituting alternate fuels for petro-diesel can greatly curtail our foreign expenditure, decrease dependency on fast depleting fossil fuels reserves and meet the environmental concerns.

Of all the available alternate fuels for petro-diesel, bio-diesel is the most promising one and has many advantages over the conventional petro-diesel. Bio-diesel is renewable, bio-degradable, environmental friendly, non-toxic, portable, readily available and eco-friendly fuel.[6-9] Bio-diesel is most commonly referred to a vegetable oil or animal fat (preferably vegetable oil) based diesel engine fuel consisting of long chain alkyl (Methyl, Ethyl or Propel) esters, that is typically produced by chemically reacting lipids (e.g. vegetable oil, animal fat) with an alcohol.[10,11]Traditionally, both edible and non-edible vegetable oils have been used for bio-diesel production. However, due to "Food vs Fuel" concern and also for the India's National Policy on Bio-fuels 2009, non-edible vegetable oils have become the catch of the day.[12]

Among non-edible vegetable oils, soap nut (*Sapindus Mukorossi*) oil is a potential feedstock for bio-diesel production and is a recent introduction in the field of bio-diesel research. Although a new substitute to petro-diesel, many researchers have contributed to the study of diesel engine performance using soap nut bio-diesel and its blends with petro-diesel as alternate fuels.[13-27]In 2012, **Chen, Chiang and Chen**[17]showed that both the soap nut bio-diesel and jatropha bio-diesel had complimentary fuel properties. The bio-diesel blend of 35% soap nut bio-diesel to 65% jatropha bio-diesel by weight satisfied all the biodiesel specifications. Moreover, volumetric blends of optimized bio-diesel with petro-diesel of up to 40% (B40) showed satisfactory fuel properties, to be used as alternate fuels for diesel engine.

In 2013, **Chanchiang and Chen**[21]revealed that the soap nut bio-diesel had satisfactory fuel properties to be a potential bio-diesel, except for a high CFPP of 6ºC. The predominant components of soap nut bio-diesel were methyl at 55.2 wt% and methyl lsocynate at 23.9%. The efficient range of blending composition for blends of soap nut bio-diesel with petro-diesel was found to be from 5% (B5) to 20% (B20). Also, the properties of blends were described by linear correlations.

In 2013, **Chakraborty**[22] showed that both the soap nut and beleric oils were potential feed stocks for bio-diesel production, as well as both the soap nut and beleric bio-diesels met the required bio-diesel specifications. Furthermore, investigation revealed that the increase in brake thermal efficiency (BTE) associated with the decrease in specific fuel consumption (SFC), by the increase in engine load had been the characteristic feature for all the bio-diesel blends, as well as of petro-diesel. At medium load condition, performances of bio-diesel blends were better than petro-diesel as exhibited by relatively higher BTE. However, among bio-diesel blends, bio-diesel blends of soap nut performed better as compared to the bio-diesel blends of beleric. The BTE of the engine with B10 blend of soap nut was 27.1%, whereas with B10 blend of beleric relatively lighter load was 16.76%. The similar trend of variation of BTE was also observed at higher level of engine loading. It was found that with the increase in bio-diesel percentage of the blends, the emission of CO, HC and PM decreased, whereas, NO x emission increased as compared to petro-diesel. Overall, acceptable performances were observed for both the types of bio-diesel blends up to 20% of blending, with B10 blend of soap nut performing better than the rest.

In 2013, **Subhash, Prasad and Pasha**[25]investigated, to compare the effect of varying combustion chamber geometry on the performance, emission and combustion characteristics of a compression ignition (CI) engine, using a bio-diesel blend of 20% soap nut bio-diesel and 80% petro-diesel i.e. B20 as engine fuel. The investigation showed that the BTE was higher, whereas, BSFC was lower for Toroidal Combustion Chamber (TCC) as compared to Hemispherical Combustion Chamber

(HCC) at all loads of engine operation. Also, significant reduction in the emissions of particulates, CO and HC were noted for TCC. However, NO_X emission was slightly lower for HCC. Ignition delay was lesser for TCC as compared to HCC. In short, TCC showed better characteristics compared to HCC. Moreover, experimental investigation revealed that engine characteristics using soap nut bio-diesel blends as fuel, can be significantly improved by suitably designing the combustion chamber.Thus, much work has been done on soap nut bio-diesel, however, much need to be done. So, a research work was undertaken with the following objectives:

To experimentally investigate and compare the performance of a single cylinder four stroke diesel engine using petro-diesel and lean bio-diesel blends

Blend as alternate fuel for diesel engine, so as to curtail our foreign expenditure, decrease dependency on fast depleting fossil fuels reserves and meet the environmental concerns.

2. MATERIALS AND METHODS

A single cylinder four stroke compression ignition engine, installed at Thermal Engineering Lab of UIT, RGPV, Bhopal (MP) as shown in Plate 3.1, was employed for evaluating engine performance parameters. The technical description of the test engine is as shown in Table 3.1.

Plate 3.1 Experimental Setup

Table 3.1: Technical Specifications of the Test Engine

Parameter	Description
Engine	Diesel Engine
Make	Kirloskar Oil Engine, Pune
Model	SV1
Type	Vertical, Totally Enclosed, Four Stroke Cycle, Water Cooled, Compression Ignition
No. of Cylinders	One
Bore (D)	87.5 mm
Stroke (L)	110 mm
Cubic Capacity	662 cc
Compression Ratio (r_C)	16.5:1
RPM	1800
Rated Output	8 HP

The petro-diesel (B0) and lean soap nut bio-diesel blends of 5% (B5), 10% (B10), 15% (B15) and 20% (B20) with petro-diesel by volume, were used as engine fuels for experimental investigation. For the purpose, petro-diesel and soap nut fruits were purchased from local market of Bhopal, and soap nut bio-diesel was obtained from Soap nut fruits by drawing oil from their kernel through cold pressing followed by Trans etherification. The fuel properties of petro-diesel and soap nut bio-diesel were evaluated using ASTM and EN Standards as shown in Table 3.2.

Table 3.2 Fuel Properties of Soap nut Bio-diesel and Petro-diesel

Serial No.	Property	Soap nut Bio-diesel	Petro-diesel
1	Cloud Point (^{0}C)	-1	-12
2	Pour Point (^{0}C)	-4	-15
3	CFPP (^{0}C)	5.5	-10
4	Flash Point (^{0}C)	165	55
5	Kinematic Viscosity at 40 ^{0}C (mm^2/s)	4.630	2.780
6	Cetane Number	56	46
7	Density at 15 ^{0}C (kg/L)	0.874	0.850
8	Acid Number (mgKOH/g)	0.140	0.102
9	Carbon Residue (%m/m)	0.012	0.1
10	Iodine Number (gI$_2$/100 g)	82	-
11	Calorific Value (MJ)	40.020	42.390
12	Sulphur Content (mg/kg)	102	250
13	Sulphated Ash Content (%m/m)	0.001	0.01
14	Lubricity (WSD/mm)	0.181	0.450
15	Workmanship (visual)	Clear and Free	Clear and Free

3. TEST PROCEDURE

The test engine was started without any load (however, engine friction was always present).Before starting the test, the engine was kept running for 20 minutes to get stabilized, and there after stabilization period of 15 minutes was allowed for subsequent tests. At first the tests were conducted using petro-diesel as fuel by varying the load.

The selected load on the engine was applied and the engine was kept running under the desired load condition for 10 minutes. Thereafter, readings were observed and recorded. The same procedure was repeated for testing the prepared soap nut bio-diesel blends. After completion of the tests o n one of the blends, the remaining fuel from the fuel tank was drained off fully to avoid any mixing of the prepared blends.

Then the next prepared blend was filled into the fuel tank and the engine was run for 15 minutes duration for its stabilization and combustion of remaining fuel in the pipeline, as well as in the injection systems. The experiments were conducted for each blend and three repetitions were made on each setting of load. Finally, results of engine performance with soap nut bio-diesel blends were compared with that of petro-diesel.

4. RESULTS AND DI SCUSSION

Experimental data were collected at different loads through repeated experimental observations, by using the aforementioned diesel engine and fuels. The data thus collected were analyzed and represented in graphs as shown below:

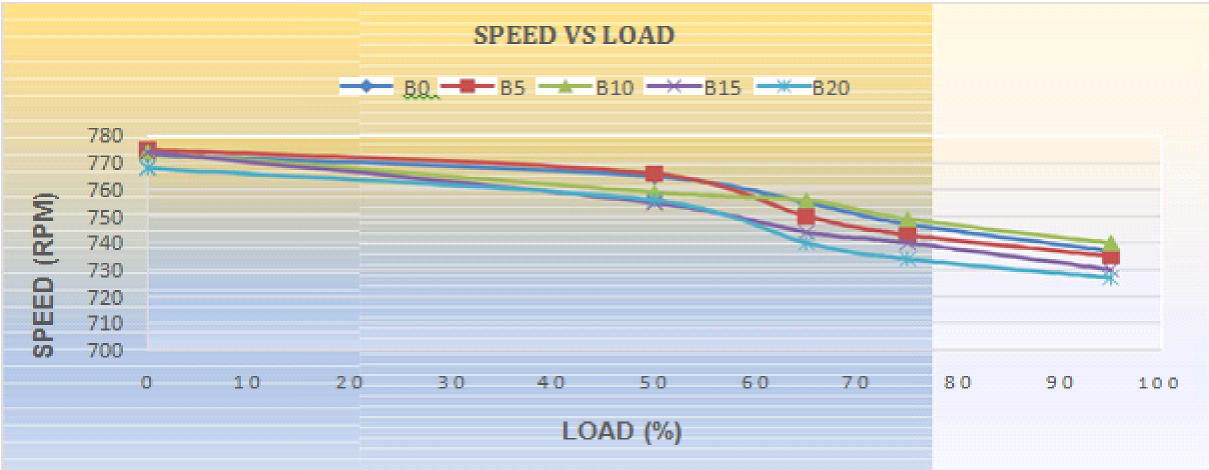

Fig. 3.1: Speed vs. Load for Petro-diesel and the Blends

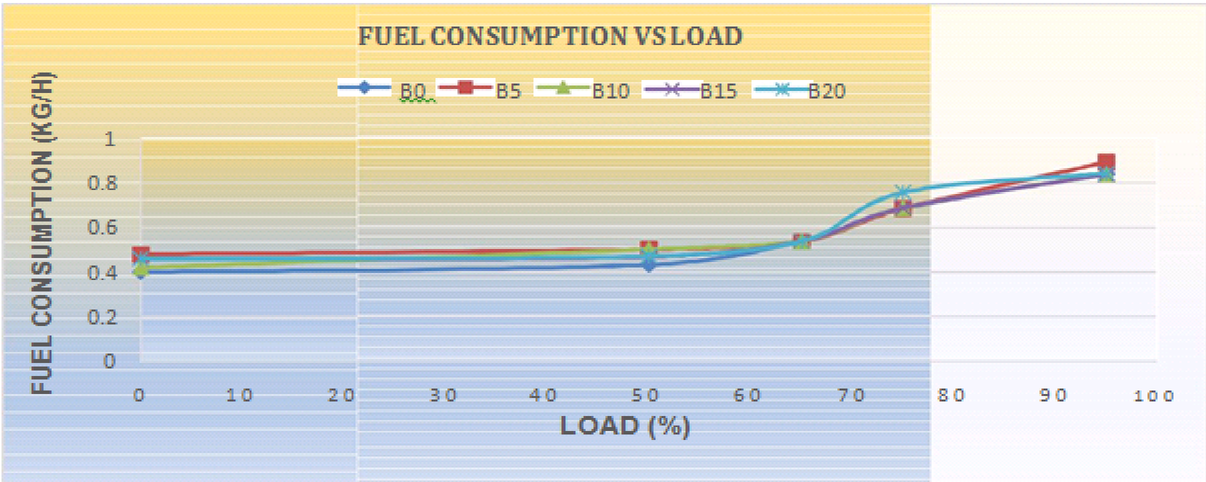

Fig. 3.2: Fuel Consumption vs. Load for Petro-diesel and the Blends

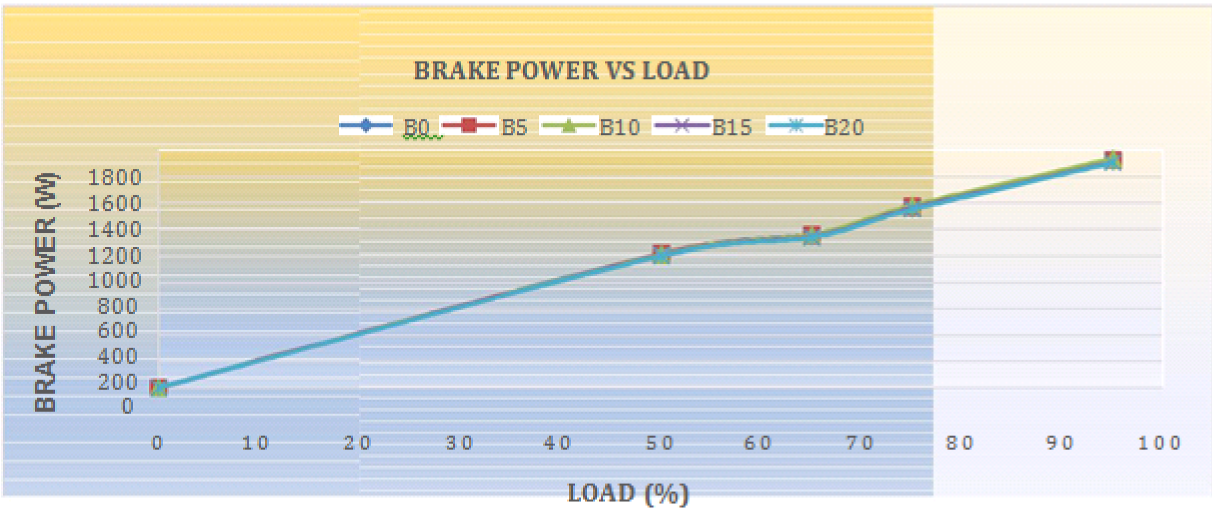

Fig. 3.3: Break Power vs. Load for Petro-diesel and the Blends

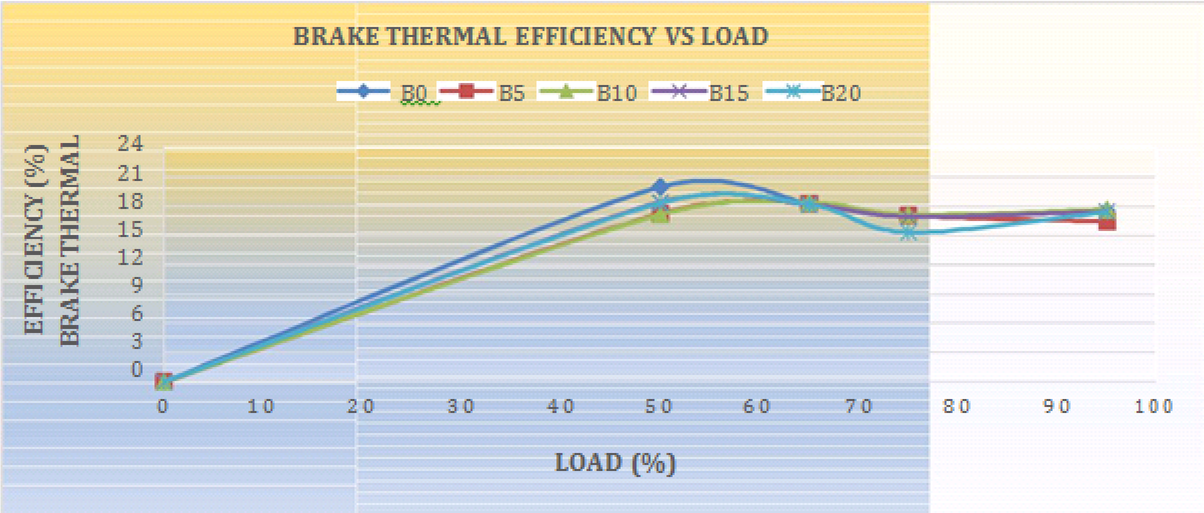

Fig. 3.4: Break Thermal Efficiency vs. Load for Petro-diesel and the blends

At no load condition, the values of various engine performance parameters were within reasonable limit for petro-diesel and bio-diesel blends with petro-diesel. As load increased, the behavior of petro-diesel and bio-diesel blends with petro-diesel became more and more evident.

In fig. 3.1, Speed is plotted against the Load for petro-diesel and blends of bio-diesel with petro-diesel. In the beginning, speed is nearly same for petro-diesel and all the blends, except for B20, which has the lowest value. Afterwards, speed decreases for petro-diesel and the blends, as the load increases. During the load interval 50% - 62.5%, petro-diesel and the blends exhibit sharp reduction in speed, except for B10. This is for the reason that after medium load, fuel consumption increases considerably to account for increasing energy demand, but this increase is gradual in the beginning. So, petro-diesel and the blends don't have sufficient amount of fuel to compensate for the load increment, however, calorific value and oxygen content of B10 are just ideal to ensure proper and efficient combustion for releasing optimum heat energy, and so speed reduction of B10 is gradual as Compared to petro-diesel an d other blends. Moreover, for the load interval 62.5% - 9 3.75%, at any given load, B10 has the highest value and B20 the lowest value for speed. The low performance of B2 0 is for the reason that though B20 has high oxygen content, its calorific value is low due to high percentage of bio-diesel, and so even with proper and efficient combustion, amount of heat energy released is low as compared to petro-diesel and other blends.

In fig. 3.2, Fuel Consumption is plotted against the Load for petro-diesel and blends of bio-diesel with petro-diesel. In the beginning, fuel consumption is nearly same for petro-diesel and B10, while is nominally higher for the remaining blends with maximum for B5. Afterwards, fuel consumption increases for petro-diesel and the blends, as the load increases. For the load interval 0% - 62.5%, fuel consumption for petro-diesel and the blends shows minimal increase; whereas, for the load interval 62.5% - 93.75%, the increase is steep. The rise in fuel consumption is for the reason to provide for excess energy demand aroused due to increasing load. Moreover, at 75% load, B20 has 10.4 % more fuel consumption than that of petro-diesel, as for the obvious reason of low calorific value, and at 93.75% load, B5 has maximum fuel consumption (might be due to improper combustion) of 0.893 kg/h i.e. 6.2% more than that of petro-diesel, while that of the others are nearly same.

In fig. 3.3, Brake Power is plotted against the Load for petro-diesel and blends of bio-diesel with petro-diesel. Brake Power increases smoothly for petro-diesel and the blends, as load increases. Over the entire load range, brake power at any given load is slightly higher for petro-diesel as compared to the blends, with the only exception for 62.5% - 93.75% load range, where B10 finds the top notch. This is for the reason that though for the load interval 62.5% - 93.75%, amount of fuel consumption is more or less same for both petro-diesel and B10, however, better combustion of B10 due to high oxygen content results in better heat energy release.

In fig. 3.4, BTE is plotted against the Load for petro-diesel and blends of bio-diesel with petro-diesel. In the beginning, BTE is highest for petro-diesel, while for the blends is slightly lower. At 75% load, BTE of B20 is 9.8% lower than that of petro-diesel. At the final point of the load range as compared to the initial point, the BTE is slightly lower for petro-diesel and the blends, except for B10 (0.8% more than petro-diesel). Moreover, during the entire load range, BTE only varies slightly and also has low value for petro-diesel and the blends. Here, the marginal better performance of B10 is for the proper and efficient combustion releasing better heat due to the balanced proportion of bio-diesel in the blend.

In short, performance of petro-diesel and soap nut bio-diesel blends were satisfactory and within reasonable limits. However, overall performance of B10 was marginally better than the rest.

5. CONCLUSIONS

The present work was undertaken to experimentally investigate the engine performance of a single cylinder, four stroke water cooled diesel engine using petro-diesel and lean soap nut bio-diesel blends with petro-diesel as engine fuels. The investigation was performed for medium to high load range of 50% - 93.75%. The load range of 50% - 93.75% was chosen as it's the major operational load range of an engine.

The experimental investigation enabled in drawing the following conclusions:
Petro-diesel and all the blends exhibited satisfactory engine performance over the entire load range. For the medium load range of 50% - 62.5%, B10 showed better performance than the rest for speed, fuel consumption and BTE, with 0.2% more BTE than petro-diesel at 62.5% load. Whereas, petro-diesel performed better for BP. Moreover, for the high load range of 62.5% - 93.75%, B10 performed better than the rest for speed, fuel consumption, BTE and BP as well, with 0.2% more BP and 0.8% more BTE than petro-diesel at 93.75% load .All

The lean soap nut bio-diesel blends viz. B5, B10,B15 and B20 performed reasonably well and were found to be potential alternate fuels for diesel engine. Among the lean soap nut bio-diesel blends, B10 was found to be the most feasible blend as alternate fuel for diesel engine.

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