JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

COMBUSTION, PERFORMANCE AND EMISSION BEHAVIOR OF SOAP-NUT OIL BIODIESEL/DIESEL BLENDS IN DI DIESEL ENGINE WITH DIETHYL-ETHER ADDITIVE

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Received: 14 March 2020 Revised and Accepted: 8 July 2020

ABSTRACT: This paper investigates the of soap-nut oil biodiesel/diesel blends are experimentally tested in a single cylinder DI diesel engine to analysis the performance, combustion and emission characteristics. The soap-nut oil was converted into biodiesel through Trans-esterification technique. The soap-nut oil biodiesel were blended with at different proportions to diesel fuel at 10, 15 and 20%. Among the blends B10 gave better performance in all aspects except NOx emission. To improve NOx emission diethyl-ether (5% by volume) was used in the B10.The results of B10+DEE give almost producing similar BSFC and BTE with diesel and NOx emission decreased by 32.1% than B10.Therefore addition of 5% DEE to 10% of soap-nut oil biodiesel as a good substitute fuel for diesel in a diesel engine.

KEYWORDS- Soap-nut oil, biodiesel, transesterification, additive, diethyl-ether

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I. INTRODUCTION

In the near future, the non-renewable hydrocarbon fuels which are going to be deplete soon. Alongside, the release of CO_2 (amount) by burning diesel is confined in the earth atmosphere, which in-turns increasing the earth's temperature leads to global warming [1, 2]. However, the release of CO_2 by the biodiesel would be consumed by plants. In this regards, the only way to reduce the CO_2 amount formed from IC engines is to use of renewable biofuels. The alternative fuel is easily available, technically feasible and economically competitive. Biodiesel is a biodegradable and nontoxic considerably free from sulphur and aromatics nature from natural sources and it has low emanation ace records, which can be utilized straight forwardly in IC engines. It is an appealing offer as constant inexhaustible biomass effortlessly accessible from plants, vegetables, and creature fat combined with ecological advantages [3]. Since biodiesel holds fundamentally the same as qualities to diesel, so it can be blended homogenously in any extent. However there are some disadvantages of using the straight biodiesel in a diesel engine without any modification such as cold flow properties, high oxides of nitrogen, deposition of carbon on cylinder walls, clogging of nozzles, high viscosity leads to poor atomization results in incomplete combustion, formation of gum in the presence of O_2 etc. Despite, biodiesel produced lower emission characteristics like carbon monoxide, hydrocarbon, smoke opacity, etc. To resolve the issues related with biofuels to reduce air pollution, the researchers have made severe efforts over the decades. The formation of gum problem and nozzle clogging effects can be relieved by transesterification process [4].

Nomenclature	
B0	100% Diesel
B10	10% Soap-nut biodiesel + 90% Diesel
B15	15% Soap-nut biodiesel + 85% Diesel
B20	20% Soap-nut biodiesel + 80% Diesel
B10+DEE	10% Soap-nut biodiesel + 5% Diethyl ether +85% Diesel

The utilization of biodiesel has significant potential to solve the air pollution problems in diesel engines. More well-known, the biodiesel has higher cetane number (CN) compared to diesel. Due to the higher CN in the biodiesel improves the combustion quality by decreasing the ignition time [5]. The performance, combustion and emission characteristics of a diesel engine are directly proportional to the combustion of the fuel injected [6]. Demirbas [7] studied the advantages and drawbacks of biodiesel from the edible oils (palm oil, sunflower, soybean, rapeseed etc.) and non-edible oils (mahua, jatropha, polanga, karanja, rubber seed, neem, etc.) used in diesel engines. The author reported that the main benefits of biodiesel have inherent lubricity properties which lead to its potential for decreasing a given national economy's dependency on imported crude petroleum and also higher flash point. The main drawbacks are its lower energy content, lower engine speed and power, higher price, higher cloud and pour point, higher viscosity and engine compatibility. Alongside the author concluded that the blend B20 can be directly used in all type of diesel engines without any modification and are more compatible with most distribution and storage equipment. The author reported that the PM, HC and CO emissions from the diesel engine are lowered but there is a slight increase in NOx emission. Asokan et al. [8] studied the combustion, performance and emission characteristic of kapok oil biodiesel/diesel blends in the diesel engine (DI) and reported that the emission characteristics of HC, CO and smoke opacity of B100 were decreased by 40%, 23.33% and 45.53% respectively, whereas NO_X increases slightly by 3.5% when compared to diesel fuel. Senthur Prabu et al. [9] investigated the combustion, performance and emission characteristic of diesel engine (DI) fuelled with blends of WCO biodiesel/diesel with additives of butylated hydroxytoluene (BHT) and n-butanol. These researchers reported that, B30 blend was found to be greater blend compared to other WCO blends. The BHT additive in the B30 blend showed an increase in BSFC by 7.3% and lowers in BTE by 4.6%, whereas the heat release rate were almost synchronous to diesel fuel. The n-butanol additive with B30 blend shows the CO emission lower by 37.5% and the NOx emission higher by 9%. B. Q. He [10] investigated the combined rapeseed oil and corn oil biodiesel in a modified single-cylinder diesel engine and reported that the BP was decreased by 3% and the BSFC improved by 4.5% for corn biodiesel and the BP decreased by 3% and BSFC increased by 14.5% for rapeseed oil.

In this present work, an effort has been made to study the combustion, performance and emission behaviour of single cylinder four stroke diesel engine (DI) (1500 rpm) fuelled with different blends of soap-nut oil biodiesel (SNB)/diesel (B0, B10, B15, B20 and B10+DEE) at different loads and the graphs has been plotted.

II. MATERIALS AND METHODS

Transesterification process is characterized as the procedure in which synthetically responding triglycerides, for example, one of the vegetable oil respond with alcohol in nearness of an antacid or acidic impetus to deliver glycerol and unsaturated fatty ester. In this procedure the ester is delivered when vegetable oil consolidates with basic alcohol in nearness of an impetus. The unsaturated fats of vegetable oil trade places with the (OH) gatherings of the alcohol delivering glycerol and methyl, ethyl or butyl unsaturated fats ester relying upon the sort of alcohol utilized.

Biodiesel creation requires three sources of oil or fat, alcohol and KOH (potassium hydroxide). Roughly 80% by volume of feedstock of biodiesel is soap-nut oil and around 20% is ethanol. The soap-nut oil utilized as a part of exploratory examination was gotten from market. All chemicals (Ethanol, KOH impetus) were given by compound designing lab. Ethanol might be utilized the length of it is anhydrous (with a water substance of under 2%), since the water goes about as an inhibitor response.

Readiness of biodiesel from raw vegetable oil by transesterification, it is a procedure of utilizing methanol (CH_3OH) within the sight of impetus Potassium hydroxide (KOH) to artificially break their long atomic chain of raw oil into ester and glycerol. This procedure is a response of the oil with a liquor to expel the glycerin, a side effect of biodiesel creation.

The system done is given beneath: 1000 ml of soap-nut oil is taken in a compartment. 10 grams of KOH antacid impetus is weighed. 200 ml of methanol is taken is measuring glass. KOH is blended with the liquor and it is mixed until they are legitimately broken down. Raw soap-nut oil is taken in a compartment and is blended with a mechanical stirrer and at the same time warmed with the assistance of a warming loop. The speed of the stirrer ought to be least and when the temperature of the raw vegetable oil achieves 60 °C, the KOH-methanol arrangement is filled the oil holder and the holder is shut with an air firmly. Presently the arrangement is mixed at high speeds (720 rpm). Care ought to be taken that the temperature does not surpass 60 °C as methanol dissipates at temperatures higher than 60 °C. Additionally the KOH-methanol arrangement is blended with the crude oil just at 60 °C in light of the fact that warmth is created when KOH and methanol are combined and the temperature of the raw oil ought to be more than this when blending is done if the responses need to occur legitimately.

Subsequent to mixing the oil-KOH-methanol arrangement at 60 °C for two hour the arrangement is exchanged to a glass holder. Presently division happens and biodiesel gets gathered in the upper part of the glass holder while glycerin gets gathered in the base segment. This glycerin is expelled from the holder. At that point the biodiesel is washed with water. Again glycerin gets isolated from the biodiesel and is expelled. The biodiesel is washed with water over and over until no glycerin is there in the biodiesel. Presently this biodiesel is warmed to

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

100 °C to vaporize the water content in it. The subsequent item is the biodiesel which is prepared for utilize. The following chemical structure shows (fig. 1) the transesterification of oil in to biodiesel. Alongside the fuel properties of diesel fuel, soap-nut biodiesel (SNB), DEE and diesel blends are given in the table 1.

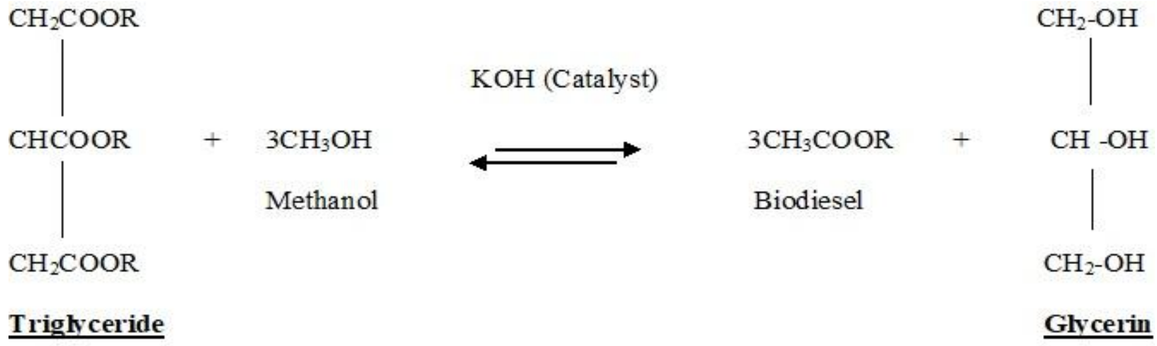

Table-1 Fuel properties of soap-nut biodiesel (SNB), DEE and diesel blends and diesel fuel

Properties	SNB	DEE	DIESEL	Testing Procedure
Flash point °C	134	-45	62	ASTM D93
Fire point °C	140	-	70	ASTM D93
Kinematic Viscosity @ 40 °C (mm^2/sec)	5.3	0.22	2.75	ASTM D445
Calorific value (MJ/kg)	37.9	33.9	43.8	ASTM D240
Density @ 20 °C (kg/m^3)	838	713	830	ASTM D1298
Cetane Number (CN)	55	125	53	ASTM D613

III. EXPERIMENTAL SETUP

The performance, combustion and emission characteristics of different blends of soap-nut biodiesel (SNB)/diesel were studied in a single cylinder 4-stroke DI diesel engine operates at constant speed of 1500 rpm. The diesel engine is coupled with an eddy current dynamometer for varying loads from 0 to 100% with an increment of 25% load. Schematic diagram of engine setup is shown in the fig. 2. Engine specifications are listed in the table 2.

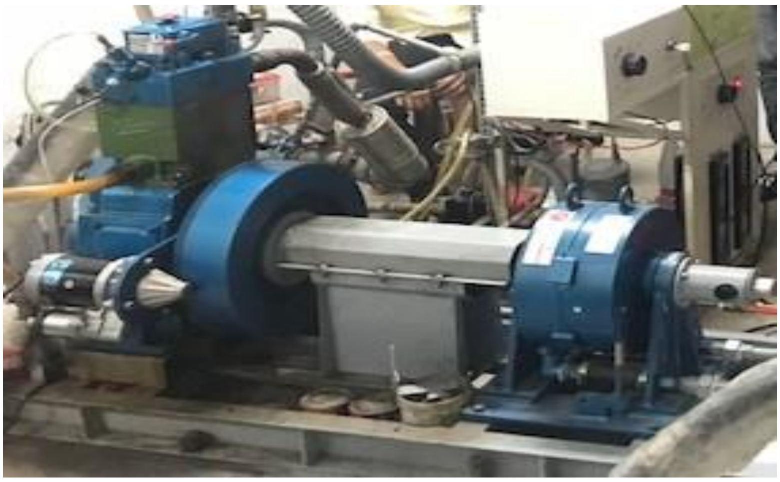

Fig. 2 Engine setup Table 2 Engine specifications

Make	Kirloskar
Model	TAF 1
Type	Direct injection, water cooled
Bore x Stroke (mm)	87.5 x 110 mm
Compression ratio	17.5:1
Swept volume	661 cm^3
Rated power	5.2 kW
Rated speed	1500 rpm
Start of injection	24˚ bTDC
Injector operating pressure	21 MPa
Connecting rod length	234

IV. RESULTS AND DISCUSSIONS

The experiment conducted in a direct injection 4 stroke diesel engine using soap nut oil biodiesel diesel blends (B10, B15, B20, B10+DEE) and diesel fuel. The performance, emission and combustion characteristics are analysed.

4.1 Performance Studies

4.1.1 Brake Thermal Efficiency

Fig.3 shows the variation of brake thermal efficiency of soap nut oil biodiesel/diesel blends at different load conditions. The brake thermal efficiency increases with increase in load. At higher loads, the BTE of B10, B10+DEE, B15, B20 and D100 are 34.52%, 34.58%, 34.27%, 33.06%and 33.63% respectively. It is observed that BTE of lower blends with addition of DEE is slightly higher than diesel fuel due to maximum temperature of the combustion zone, creates better evaporation and mixing of the soap nut biodiesel, results increasing brake thermal efficiency at higher loads. Similar results obtained by the researcher [11].

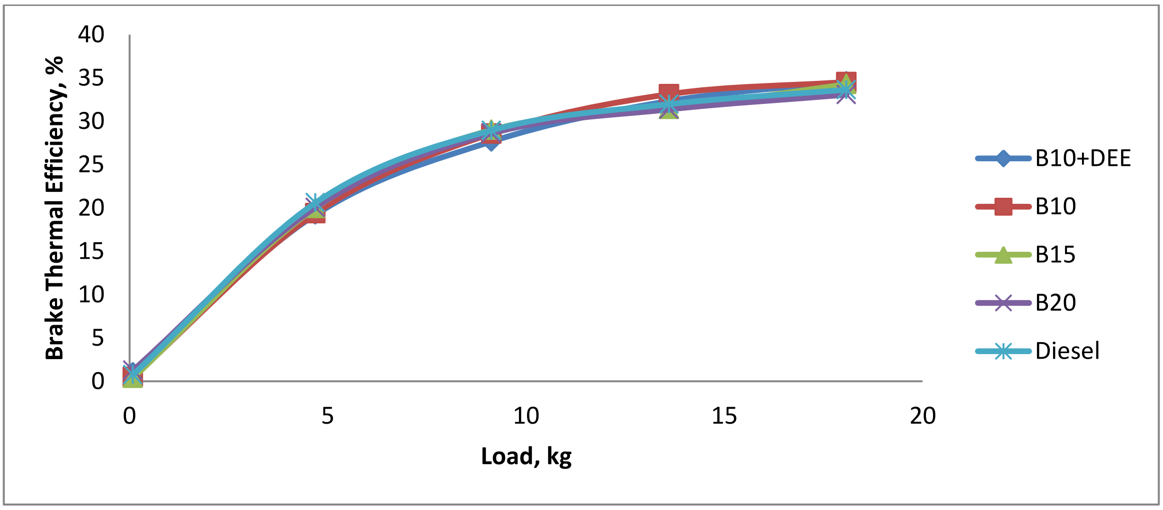

Fig. 3 Brake Thermal efficiency vs Load

4.1.2 Brake specific fuel consumption

Fig. 4 shows the variation in brake specific fuel consumption of different soap nut oil biodiesel/diesel blends and diesel at various loads. The results indicates that if the load increases BSFC values decrease up to 75% load and then increase slightly at higher loads. The BSFC at 75% load for B10, B15, B20, B10+DEE and D100 are 0.282, 0.286, 0.315, 0.305 and 0.25 kg/kWh respectively. It is observed that BSFC of B20 shows higher than other fuels. Diesel fuel operation shows minimum BSFC compare to other fuel blends (B10, B15 and B20) because of lower heating values of biodiesel. BSFC is directly related to quantity of fuel injected and the heating value of the fuel. For these, reason for increasing of BSFC soap nut oil biodiesel blended fuels. For B10+DEE shows almost similar to B10 and slightly higher than diesel fuel due its lower heating value and higher latent heat of vaporization DEE. This result is in concordant with previous studies [12].

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

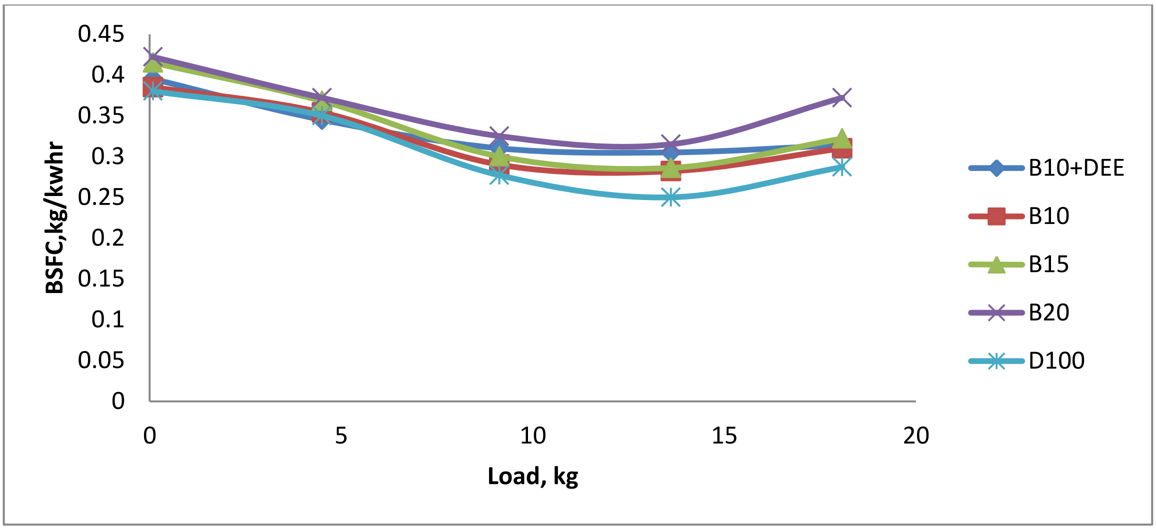

Fig. 4 Brake Specific fuel consumption vs Load

4.2 Combustion Studies

4.2.1 Cylinder Pressure

The cylinder pressures of all soap nut oil biodiesel fuels are similar to diesel trend for all working conditions. The maximum cylinder pressure observed from Fig. 5 for various blends B10, B15, B20, B10+DEE and D100 are 68.11bar, 66.31bar, 66.18bar, 61.96bar and 70.55bar respectively and attained very nearer TDC for all fuels. Because of higher pressure, the temperature of the combustion chamber also increases causes higher evaporation and mixing takes place inside the combustion chamber leads complete combustion. And it is found that maximum cylinder pressures for biodiesel blended fuel are lower than diesel is lack of heating value of biodiesel and DEE [13].

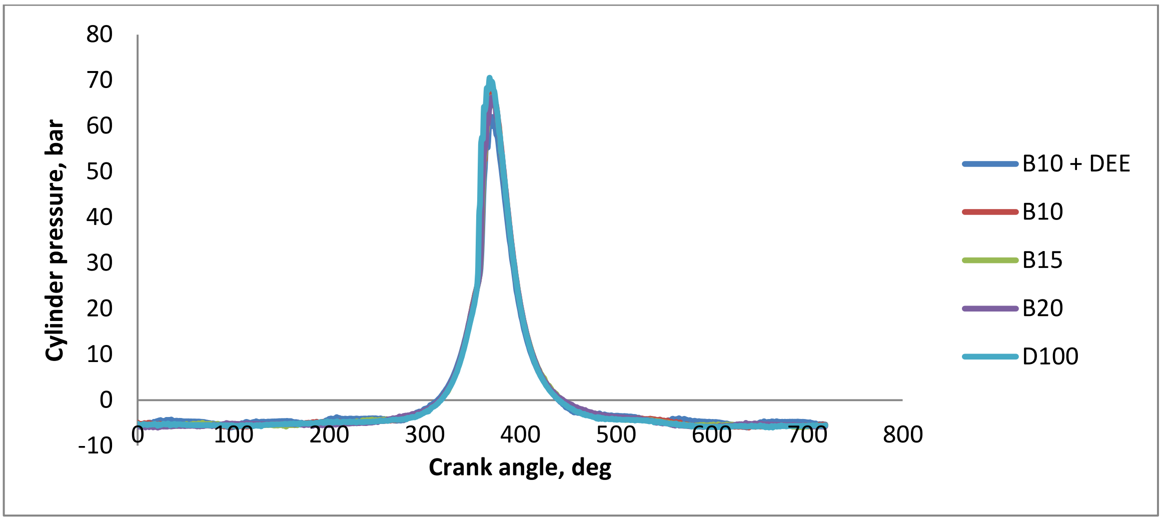

Fig. 5 Cylinder pressure vs Crank angle for full load

4.2.2 Heat release rate

The highest heat release rate for B10, B15, B20, B10+DEE, and D100 are 64.19 kJ/m^3, 62.93 kJ/m^3, 64.19 kJ/m^3, 56.51 kJ/m^3 and 69.40 kJ/m^3 respectively are occurs at very close to TDC. This rapid rise in heat release rate proved the instant of combustion beginning. The rate of heat release was rapidly raised after initiating the combustion due to the more amount of burning fuel that accumulated in the combustion chamber during the ignition delay period. However, the maximum heat release rate obtained during the rapid combustion phase was significantly higher for diesel in comparison with other tested fuels combustion phase was significantly higher for diesel in comparison with other tested fuels, as shown in fig. 6 because cetane number was low in diesel fuel. Heat release rate for B10+DEE was low compare to other tested fuels due to cetane number (CN) of DEE was too higher and heating value of DEE is also low compared to diesel fuel and biodiesel fuels [12].

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

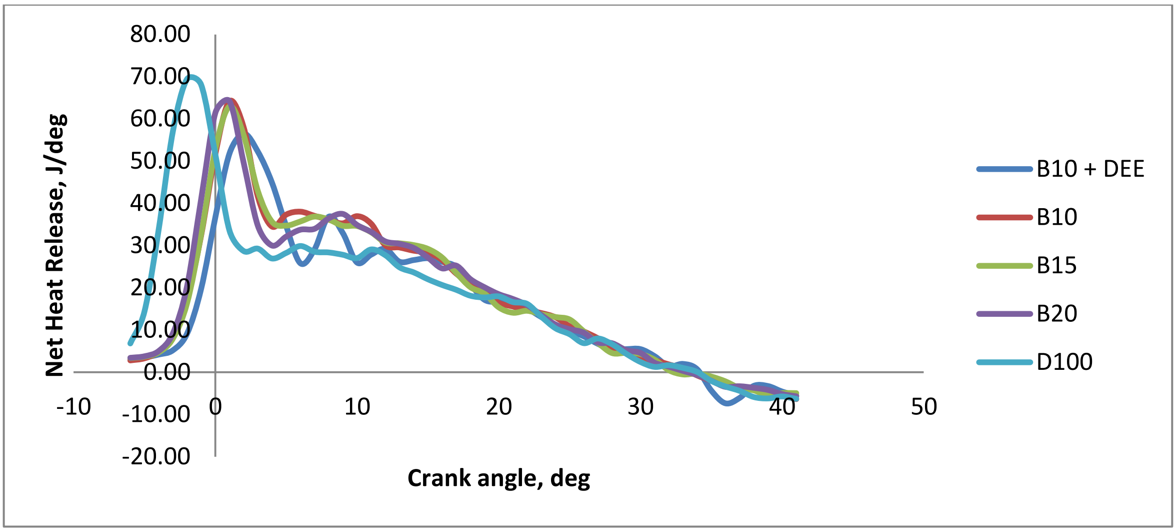

Fig. 6 Heat release rate vs crank angle at full load.

4.3 Emission Characteristics

4.3.1 CO Emission

Low combustion and high rich fuel air ratio are the major reasons for CO emissions from IC engines. Higher CO emissions causes in low power of the engine. The variation of CO emissions with load and 5% volume concentration of DEE is demonstrated in fig.7. At full load, CO emissions were observed for B10, B15, B20, B10+DEE and D100 are 0.037%, 0.04%, 0.059%, 0.112% and 0.165% respectively. It indicates that, the addition of DEE in B10 increases the CO emissions than other biodiesel blends due to incomplete combustion, insufficient residence time, too low or high equivalence ratios are part of those reasons [14].

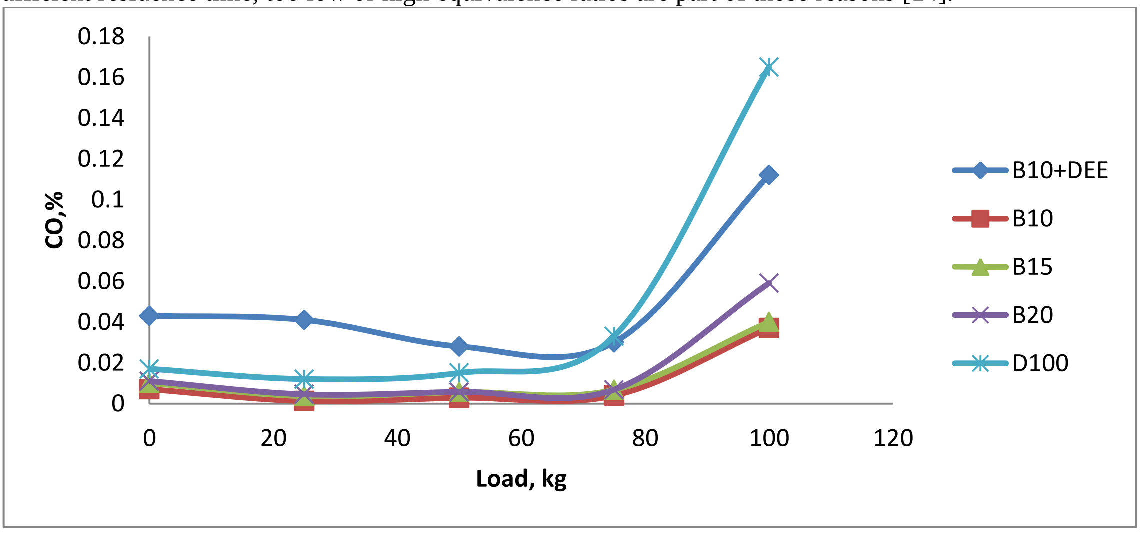

Fig. 7 Carbon monoxide (CO) vs load

4.3.2 HC emission

The HC emissions for biodiesel mixture, diesel and 5% volume concentration of DEE are shown in Fig. 8. At full load, CO emissions were observed for B10, B15, B20, B10+DEE and D100 are 59ppm, 52ppm, 48ppm, 51ppm and 78ppm respectively. It is clear that addition of DEE led to some decrease in HC emissions at all the loads compare to diesel. But compare to biodiesel blends DEE increases the HC emission due to reduction of oxidative free radical formation at higher loads [3] and also various factors like operating conditions and air-fuel mixture and fuel properties are the reason for increasing HC emissions.

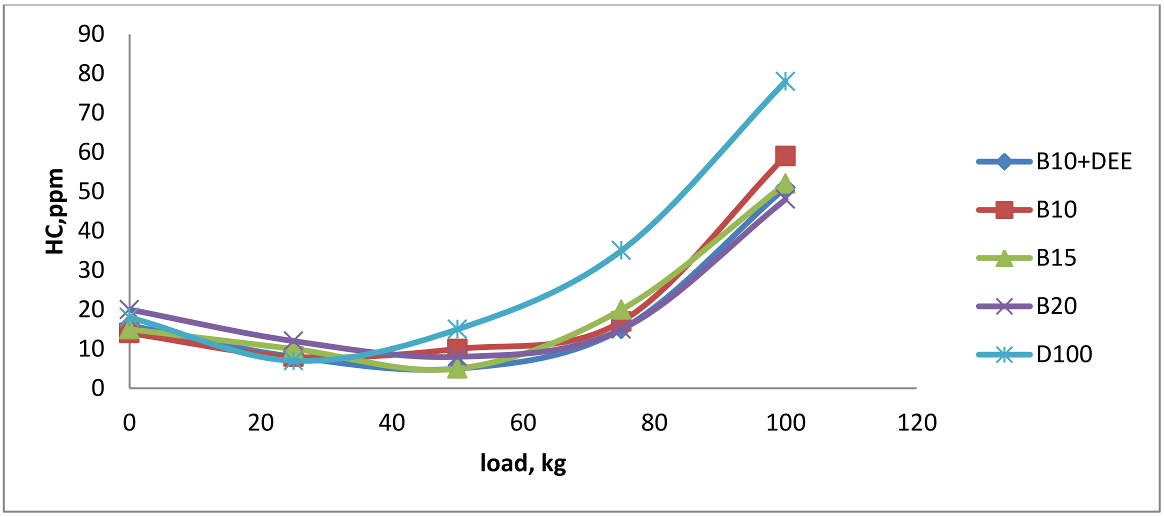

Fig. 8 Hydrocarbon vs Load

4.3.3 Nitrox oxide emission (NOx)

Fig. 9 shows NOx emission for all tested fuels with respect to various loads NOx is the most undesirable pollutant that should be minimized during combustion stage. NOx produced mainly higher combustion temperature and longer combustion duration during combustion, local oxygen concentration. At higher loads biodiesel blends B10, B15 and B20 produced higher NOx emission compared to D100. As biodiesel is an oxygenated fuel and possesses a shorter ignition delay due to higher CN, it is expected that pure biodiesel as well as its blends will lead to improved combustion and hence higher NOx formation. DEE addition to the B10 has shown a positive impact on reducing NOx emission measured of 32.1% relative to B10. The lower exhaust gas temperature supports this NOx reduction [15].

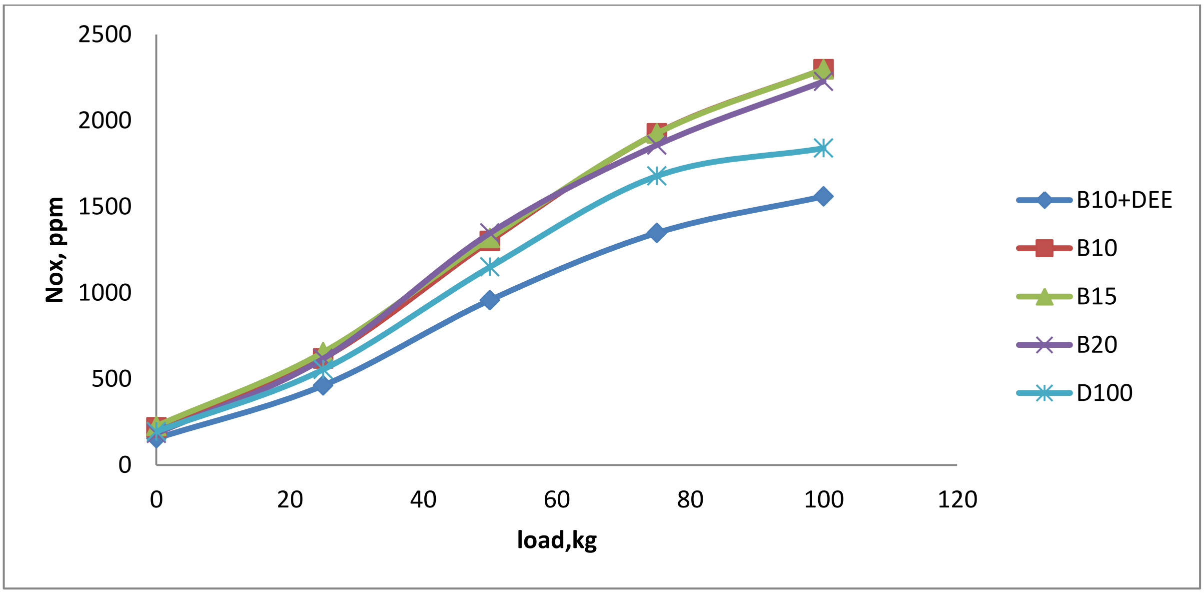

Fig. 9 Nitrox oxide vs Load

4.3.4 Smoke Opacity

Fig.10 shows the variation of smoke opacity in percentage vs load for different blends of soap nut-oil biodiesel, with diethyl ether and diesel fuel. Smoke is mainly depends on how much oxygen available in the fuel is the major factor to reduction in smoke, from the fig.10, it is observed that an increase in the smoke opacity for all blends at full load conditions. Moreover, from the results, the addition of DEE B10 blend shows an increase in smoke because of reduction in oxygen [13].

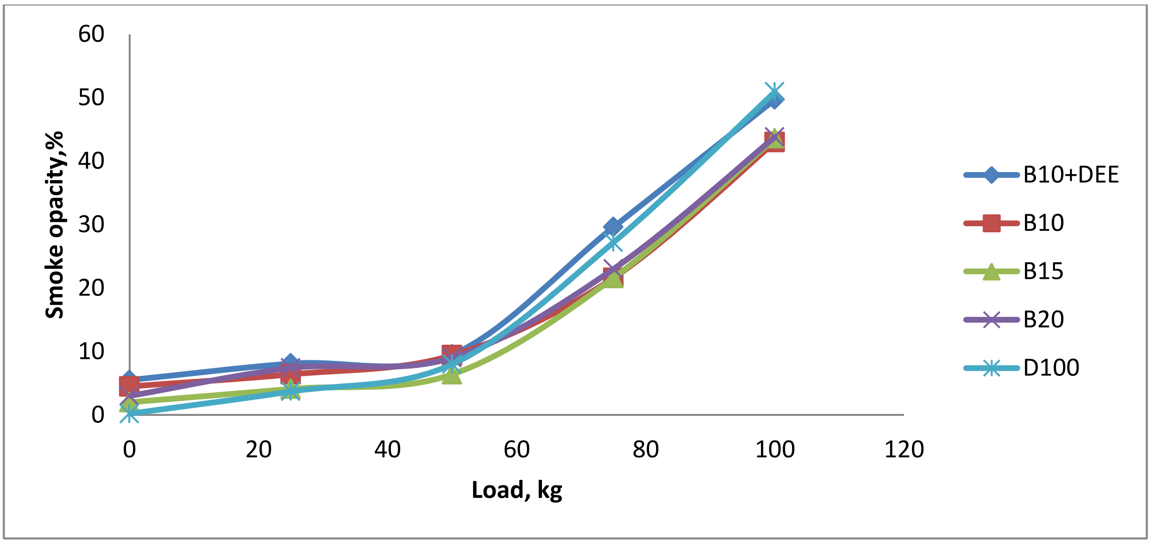

Fig. 10 Smoke opacity vs Load

V. CONCLUSION

In this experiment production of soap-nut oil biodiesel through transesterification was done gives 80% yield. Measured fuel properties of soap-nut oil biodiesel are in-line with standard biodiesel specification. Soap-nut oil biodiesel blends (B10, B15, B20, B10+DEE) successfully used as a source of fuel in DI diesel engine. BSFC is most elevated for B10+DEE mixer at 25% load which is 0.345 kg/kWh, which is almost closer to diesel which is 0.35 kg/kWh, at 75% load condition all fuels consume very low quantity .Brake thermal efficiency of B10+DEE slightly higher than diesel which is 2.9% higher than diesel fuel. The cylinder pressure and heat release rate of B10+DEE is slightly lesser than diesel fuel leads smooth engine operation. CO and HC emissions increased due to addition of DEE with biodiesel due to due to reduction of oxidative free radical formation at higher loads. B10+DEE have considerably reducing NOx emission which is 32.1% lesser to B10. This experimental result confirms that using soap-nut oil biodiesel with additives also one of the alternative fuel in diesel engines.

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