Performance and emission analysis of SOME (*Schleichera oleosa* oil methyl ester) on DI diesel engine

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Abstract

Unlimited extraction and excessive consumption of conventional fuel is the matter of serious concern. To reduce the energy dependency and simultaneously improve agriculture economy, it is necessary to replace the conventional fuel with alternate fuels. The current research is focussed on conversion of Kusum oil (*Schleichera oleosa*) into biodiesel by adopting the two-step transesterification process since the content of fatty acid is high in oil. The thermophysical properties are tested based on the ASTM standards in comparison with conventional diesel. Experimental investigations are carried out on single-cylinder water-cooled DI diesel engine coupled with eddy current dynamometer at different loading conditions with biodiesel blends (B25, B50, B75 and B100) at constant speed of 1500 rpm for studying the emission and performance characteristics for DI engine. Results reported that at full load, higher combustion efficiency and lesser ignition duration resulting in a rise of brake thermal efficiency when a larger quantity of fuel is injected. The further study included emission and performance analysis with 10% EGR, engine performance like BTE, BSFC and BSEC is slightly increased with 10% EGR, and emissions like CO₂, CO, HC are increased, whereas nitric oxide emission is reduced.

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Graphic abstract

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1 Introduction

Bio-fuels are considered as sustainable fuel sources that are important in minimising the emissions through greenhouse gases which in turn improves the quality of air [1]. To achieve environmental and economic sustainability, we require renewable and carbon-neutral bio-fuels [2]. If conventional fuels are replaced by bio-fuels which lowers

GHG emissions and enhancing rural development goals [3]. Yadav et al. [4] investigated the impact of Kusum oil composition for the extraction of biodiesel blends from Kusum seed, and the fuel properties of both are analysed. Yadav et al. [5] examined the emission and performance properties for diesel engines fuelled by SOME through the hydrodynamic cavitation process. The biodiesel blend that consists of 10, 20, 30 and 50% extracted from *Schleichera oleosa* oil is compared to diesel fuel. Pali et al.

[6] performed experimental analysis with different compositions of biodiesel blends (methyl ester). Multiple test fuels are prepared with the blending of 10%, 20%, 30% and 40% of KB in diesel. Karthickeyan et al. [7] investigated the impact of low viscous biofuel in diesel engine by using suitable catalytic reduction techniques to reduce the exhaust gases. Karthickeyan et al. [8] conducted an experimental analysis on Pistacia Khinjuk biodiesel in diesel engine to lower BSCO, BSHC and smoke emissions. Results reported that at full loads conventional fuel and B20 comparatively showed lesser engine exhaust emissions.

Jindal [9] conducted an experimental analysis with different compositions of biodiesel blends (Jatropha blends) on a diesel engine. BSFC is reduced by 10%, and HC and EGT increased but CO and smoke decreased. However, Hanumanth reported that BTE of engine operating with biodiesel mode were 22.2%, 30.6% and 37.5% at 2, 2.5 and 3.5 kW load condition. At 3.5 kW load condition, exhaust gas temperature is 19% higher. Chang Sik pee carried out an analysis on the extraction of soybeans methyl ester blended with conventional fuel on diesel engine. Experiment has been carried out at varying speeds and fuel injection pressure. Results reported that the lowest NO_x was found at 2000 rpm, and HC and CO emission was found lower at all speed. Ramadas et al. [10] utilised rubber seed methyl ester blends with diesel on 4 stroke compression ignition diesel engines. We noticed that maximum BTE was obtained by about 28% for B10. The BTE obtained while using B50, B75, B100 are 25, 25, and 24%. For all fuel tested, BSFC was decreased by an rise in load as compared with diesel. Sudipta Choudhury et al. [11] conducted an experimental analysis with different compositions of biodiesel blends (Karanja methyl ester blends) diesel engine at a constant speed with a variable compression ratio. Maximum BTE was obtained about 33.74% for B25 and 33.54% for B20. Singh et al. [12] conducted an experimental analysis with different compositions of biodiesel blends on a diesel engine. The BTE of the engine with Karanja methyl ester blends was slightly better than the conventional diesel, and also, the EGT was found to increase with Karanja methyl ester blends because of coarse fuel spray formation and delayed. Rahman et al. [13] investigated the effect of macadamia oil with a variable composition (5–20%) on a DI diesel engine to know biodiesel production from macadamia and its fuel properties. Kumar et al. [14] studied the impact of Kusum oil on the ignition characteristics of a diesel engine to know the biodiesel properties with the assistance of an ultrasonic bath. Xu et al. [15] carried out an experimental analysis with different compositions of biodiesel blends (Jatropha biodiesel) to examine the working of the diesel engine. To optimise input variables RSM, desirability function is adopted leading to enhancement in thermal efficiency.

Karthickeyan [16] investigated the effect of piston bowl geometry on the performance and emission characteristics with biodiesel blends in diesel engine. It was reported that diesel and piston bowl 1 showed higher brake thermal efficiency and lower fuel consumption than piston bowl 2. Yoon et al. [17] conducted experimental analysis with different compositions of biodiesel blends (Ethanol blends) on a diesel engine. Results reported that the performance and emission characteristics of both the fossil fuel and biodiesel blends show similar trend. However, since it has low calorific value ethanol blends reported comparatively lesser combustion characteristics. Chokri et al. [18] conducted an experimental analysis with different compositions of biodiesel blends (methyl ester) on a diesel engine. It was reported that even though the implementation of biodiesel blends leads to environmental benefits, but, however, the performance characteristics were reduced. Anbarasu et al. [19] performed an experimental analysis with different compositions of biodiesel blends (Canola biodiesel) with alumina nanoparticle additives on a diesel engine. Results reported that greater efficiency was observed in the case of alumina nanoparticles in comparison with pure Canola and fossil fuel. Singh et al. [20] conducted an experimental analysis to capture the flow phenomena by using high-speed camera and modifying the operating parameters with different compositions of biodiesel blends (binary biodiesel) on diesel engine. Gupta et al. [21] conducted experimental analysis with different compositions of biodiesel blends (Karanja biodiesel blends) on diesel engine. Results indicated that PM emission is relatively high when compared with pure diesel. Wang et al. [22] conducted an experimental analysis on pumpkin seed oil in diesel engine to study the performance, combustion and emission characteristics. Results reported that with high injection timing and pressure exhaust gases are reduced. Karthickeyan et al. [23] conducted an experimental investigation on pomegranate oil in ceramic-coated diesel engine to obtain higher temperature inside the combustion chamber leading to superior engine characteristics. Karthickeyan et al. [24] conducted an experimental analysis on raw papaya seed oil in ceramic-coated diesel engine to reduce heat losses from combustion chamber leading to reduction in CO , HC, NO_x and smoke emissions. Karthickeyan [25] investigated the impact of alternate fuels on PCCI engine to study thermophysical characteristics. Results reported that at full load pilot fuel injection exhibited lesser emission.

In the open literature [26–28], many researchers studied the effect of biodiesel blends on the emissions; however, only limited research has been carried out on the impact of the fatty acid composition. In the present study, the efforts are made to produce the biodiesel from Kusum oil (*S. oleosa* oil) and blends with conventional diesel in

Fig. 1 Transestrification setup **Fig. 2** Esterification process **a** acid catalysis, **b** separation of methanol and **c** neutralised esterified oil

various proportions to study the performance and emission characteristics. The impact of biodiesel blends at variable load and fuel injection pressure is considered as input parameters to examine the performance and emission characteristics. The rest of the paper is organised as follows: a methodology for extracting biodiesel is obtained in Sect. 2 followed by experimental setup, and results are discussed in Sects. 3 and 4.

2 Methodology for obtaining biodiesel from Kusum oil

Before the production of biodiesel, it is essential for analysing and to study the thermophysical characteristics of biodiesel. The conversion of Kusum oil (*S. oleosa*) into biodiesel takes place by 2 steps: one is acid esterification followed by the transesterification process. The prerequisite

chemical is collected from Nagpur in Maharashtra. The obtained raw Kusum oil is initially extreme red in colour. Figure 1 represents the transesterification setup used for the extraction of biodiesel.

2.1 Esterification process

Initially, the obtained raw Kusum oil appearing in extreme red is taken in a 1000 ml capacity reactor and continuously mixed by a stirrer. The collected raw oil is heated hence maximum temperature of (110–130 °C) is achieved. Now, the pre-heated raw oil is mixed with methanol (using H_2SO_4 with ratio 1:6) as a catalyst. Figure 2 represents the separation of methanol from the oil. The methanol oil mixture is taken into a separate container and waited for certain duration so that the methanol gets separated from the esterified oil. The larger density of the esterified oil gets deposited in the bottom part of the container.

Fig. 3 Transesterification process **a** preheating, **b** alkaline catalysis and **c** FAME oil

Fig. 4 Schematic diagram of experimental setup

Table 1 Engine parameters

Make	Kirloskar oil engine
Model	TV1
No. of cylinders	1
Bore diameter	87.5 mm
Stroke length	110 mm
Compression ratio	17.5
No. of strokes	4
Cylinder volume	661 cc
Fuel injection	Direct injection
Rated speed	1500 RPM
Rated output	5.2 kW
Fuel injection pressure	20–25 MPa
Fuel	High-speed diesel

Table 2 Technical data of AVL DiGas 4000 Five gas analyser

Exhaust gas measured	Measurement range	Resolution
Engine speed	250–8000 rpm	10 rpm
Oil temperature	0–120 °C	1 °C
CO	0–10% by vol.	0.01% by vol.
CO ₂	0–20% by vol.	0.1% by vol.
HC	0–20,000 ppm vol.	1 ppm vol.
O ₂	0–4% by vol	0.01% by vol
Smoke	4–22 by vol	0.1% by vol
NO _x	0–4000 ppm vol.	1 ppm vol.

2.2 Transesterification process

Initially, the obtained esterified oil is pre-heated and neutralised as shown in Fig. 3. The neutralised esterified oil is taken in a 1000 ml capacity reactor and stirred continuously by magnetic stirrer. The separated *S. oleosa* oil is then heated to a maximum temperature of 70 °C. Transesterification was carried out by using alkaline catalyst by taking a sample whose acidic value is less than 3% of Kusum oil.

The obtained transesterified oil is allowed to settle for 24 h for separating the free acid methyl ester (FAME) with glycerol layer which has occupied on the bottom of the funnel due to its higher density. Mineral water is then used for neutralising the transesterified oil. Mineral water is heated to the maximum temperature of 60 °C. Wherever proper neutralisation is not observed, mix heated mineral water with oil.

2.3 Biodiesel blends preparation

An extracted biodiesel from *S. oleosa* is mixed with conventional diesel in different compositions as follows:

- D100: 100% fossil fuel
- B25: 25% of biofuel + 75% of conventional fuel
- B50: 50% of biofuel + 50% of conventional fuel
- B75: 75% of biofuel + 25% of conventional fuel
- B100: 100% biodiesel

3 Methodology and experimental setup

Figure 4 represents the schematic representation of four stroke single-cylinder water-cooled DI diesel engine. Initially, readings are taken on a conventional Kirloskar engine with a rated output of 5.2 kW by measuring the performance and emission characteristics. To vary the load, eddy current dynamometer will be used. Exhaust gas temperatures are measured with the help of RTD measurement. Table 1 represents the specification of a diesel engine. Exhaust gases are measured with the help of AVL Digas 4000 fire gas analyser. A smoke meter is an opacimeter device working on the partial flow principle and is measured with AVL 437. Table 2 represents the specification of the exhaust gas analyser.

Experimental investigations are carried out on diesel engine at a constant speed to obtain a steady state at a temperature of 65 °C. Simultaneously, alternate fuel is supplied for some duration until the similar temperature has been reached. By varying the load (0, 3, 6, 9, 12 and 18 kg) with eddy current dynamometer at 17.5:1 (compression ratio), engine performance characteristics like BP, BMEP, BSEC, BTE and exhaust gas temperature are calculated. At each load, output parameters are measured and recorded. Exhaust gas emissions in terms of CO, unburnt hydrocarbons, NO emissions are measured with AVL Digas 4000 analyser. The above-mentioned procedure is repeated on different compositions of biodiesel blends with variable loads, and output parameters are measured.

Fig. 5 The obtained FT-IR spectrum of biodiesel from Kusum oil

Fig. 6 Brake power versus load

4 Results and discussion

Experiments are carried out on conventional Kirloskar diesel engine with different loads at a constant speed of 1500 rpm and rated output of 5.2 kW by measuring the emission and performance characteristics. To vary load, eddy current dynamometer will be used. Exhaust gas temperatures are measured by an RTD measurement. Exhaust gases are measured with the help of AVL Digas 4000 fire gas analyser. A smoke meter that is an opacimeter device working on partial flow principle is measured with AVL 437.

Tests were performed to measure both mid-infrared ranges and near-infrared ranges by adopting FT-IR absorption technique and reported that mid-infrared values were in an acceptable range. Figure 5 represents the obtained FT-IR spectrum of biodiesel in which the first

Fig. 7 Brake power versus brake thermal efficiency

peak is reported between 1000 and 1300 cm^{-1} . Similarly, the maximum peak is again observed between 1770 and 1820 cm^{-1} , where a predominately larger quantity of biodiesel is presented with a maximum peak where absorption of the carbonyl is maximum.

4.1 Performance analysis

The conventional diesel engine operates at a constant speed until a steady state is obtained at a temperature of 65 °C. Simultaneously, alternate fuel is supplied for some duration until the similar temperature has been reached. By varying the load (0, 3, 6, 9, 12 and 18 kg) with eddy current dynamometer at 17.5:1 (compression ratio), engine performance characteristics like brake power, BMEP, BSEC, BTE, exhaust gas temperature are calculated.

4.1.1 Brake power

Figure 6 illustrates varying brake power with different composition of blends when compared with conventional diesel is discussed. By the increase in load, BP increases and it achieves maximum value. At peak load, maximum brake power of 4.95 and 4.93 kW in case of B100 and B75 is observed, whereas in the case of B25 and B100 maximum brake power of 4.62 and 4.78 kW is reported. In conventional diesel fuel, maximum brake power of 5.1743 kW is observed at full load condition which is approximately 0.22–0.55 kW greater than biodiesel blends. By a rise in load, the quantity of fuel required increases resulting in higher fuel ratio and better reduction in ignition delay. In the open literature, Shahir et al. [29], it is reported that due to lower density and absolute viscosity biodiesel blends have the characteristics of quality air–fuel mixing leading

Fig. 8 Brake power versus brake specific fuel consumption

to a better atomisation for working fluid. Also, Kusum oil comprises oxygen resulting in the enhancement of better combustion. Simultaneously, it is reported that Kusum oil (*S. oleosa*) exhibits a comparatively lesser cetane number than diesel fuel. It is observed that a decrease in brake power while the composition of biodiesel increases.

4.1.2 Brake thermal efficiency

Figure 7 represents the variation of brake thermal efficiency at different loads, and brake power with different biodiesel blends is shown. It is observed that brake power increases by the rise in the load and at full load it reaches maximum. At full load condition, the maximum BTE of 22.8% and 22.72% is observed in the case of B25 and B50, whereas 21.22% and 22.55% is reported in the case of B75 and B100. In pure diesel fuel, the maximum BTE 23.42% is observed at full load which is approximately 1–2% greater when compared with biodiesel blends. It is observed by a graph, an increase in the brake power, rise in brake thermal efficiency and reaching maximum at a brake power of 4.5 kW. At full load, the thermal efficiency for fossil diesel is found to be 25.01%, whereas in case of biodiesel it is 24.78%. Basically, Kusum oil (*S. oleosa*) has low cetane number leading to leaner air–fuel mixture resulting in improper combustion because of the longer ignition delay. Also, at low load the amount of the fuel injected is lesser which also leads to improper combustion. Results reported that lesser fuel supply and longer ignition duration leads to reduction in mixing efficiency. However, at higher loads in case of biodiesel blends as larger amount of biodiesel resulting in greater mixing efficiency and lesser ignition duration resulting in increase in BTE.

Fig. 9 Brake thermal efficiency versus BMEP

Fig. 10 Load versus exhaust gas temperature

4.1.3 Brake specific fuel consumption

Figure 8 illustrates the variation of BSFC for different biodiesel blends in comparison with conventional diesel fuel. It is reported that with an increase in the brake power, brake specific consumption is decreased. At brake power of 0.94 kW, 0.496, 0.503, 0.504 and 0.506 kg/kWh, brake specific fuel consumption is noted in the case of B25, B50, B75 and B100 biodiesel blends. Simultaneously, BSFC is also found to increase with a rise in the composition of blends. This is because the rise of composition of Kusum oil leads to reduction in the calorific value and increase in mass flow rate for obtaining similar operating parameters. However, it is also observed that rise in the output power tends to lower in the BSFC for biodiesel blends as well as conventional diesel fuel.

Fig. 11 Load versus smoke opacity

4.1.4 Brake mean effective pressure

Figure 9 illustrates the variation of BMEP for different biodiesel blends in comparison with conventional diesel fuel. BMEP is defined as the mean pressure exerted by the fluid on the cross-sectional area of the piston. Results reported that rise in BMEP leading to increase in combustion efficiency and reaching maximum. At brake mean effective pressure of 4 bar, maximum BTE of 25% is reported. At BMEP of 4.5 bar, maximum BTE of 26% is observed in case of B75. Whereas in the case of conventional diesel fuel maximum efficiency of 22% is observed at BMEP of 3.5 bar. Simultaneously in case of B25, B50, B75 and B100, brake mean effective pressure between 3 and 4 bar maximum brake thermal efficiency of 20–22% is observed. At low load condition with lesser ignition characteristics in the piston bowl, geometry fuel evaporation time increases resulting in the average pressure of combustion chamber. Whereas at higher load as the temperature within the combustion chamber is higher resulting in lesser ignition delay and greater thermal energy.

4.1.5 Exhaust gas temperature

Figure 10 represents the exhaust gas temperature at different loads for different biodiesel blends in comparison with conventional diesel fuel. Basically, the exhaust gas temperature predominantly plays a significant role in fuel consumption. At full load condition, the maximum exhaust gas temperature is observed to be 227.2 °C, 261 °C, 254.4 °C and 239 °C in case of B25, B50, B75 and B100. From the figure, it is also reported that the exhaust gas temperature for conventional diesel is lesser when compared with biodiesel blends. However, decrease in the exhaust gas temperature is not related to the composition of Kusum oil in the fuel. The increase in the exhaust gas temperature is due to the breaking of molecular bonding.

From the above discussion, it can be concluded that better BTE is observed for lower exhaust gas temperature.

5 Exhaust gas analysis

5.1 Smoke capacity

Figure 11 represents the smoke capacity formation for different biodiesel blends in comparison with conventional diesel fuel. From the graphs, it is observed that at full load condition maximum brake power 65.9%, 57%, 57.2% and 60% is reported in case of B25, B50, B75 and B100 biodiesel blends. Whereas in case of conventional diesel fuel 86% of the smoke formation is reported this is approximately 20–30% greater than the conventional diesel fuel. Lesser soot formation is reported in case of biodiesel blends due to the adequate quantity of oxygen atoms present and comparatively lesser carbon in the composition of biodiesel blends leading to complete combustion. Results also reported that with an increase in the brake power soot formation also increased in both the diesel and biodiesel blends.

5.2 Carbon monoxide emissions (CO)

Figure 12 represents the carbon monoxide formation at different brake power and variable load for different biodiesel blends compositions in comparison with conventional diesel. From the results, it is observed that at full load condition maximum brake power 0.08%, 0.07%, 0.09% and 0.08% is reported in case of B25, B50, B75 and B100 biodiesel blends. At full load condition, 0.05% is reported in case of conventional diesel which is 0.01% to 0.04% lower in comparison with biodiesel blends. At low loads, higher CO emission is observed due to low in-cylinder temperature and maximum latent heat of vaporisation

Fig. 12 Brake power versus carbon monoxide emissions

Fig. 13 Brake power versus unburnt hydrocarbon emissions

Fig. 14 Brake power versus NO_x emissions

resulting in retardation of CO particles. At full loads, lower CO emission is reported in both the conventional and biodiesel blends due to increase in-cylinder temperature. Net heat release rate increases resulting in improved oxidation process, Li et al. [30]. From the results, we observe that rise in the composition of blends in diesel fuel leads to low in-cylinder temperature resulting in a higher CO emission. Higher carbon monoxide emission leads to improper combustion.

5.3 Hydrocarbon emissions

Figure 13 represents the unburnt hydrocarbon formation at different brake power and variable loads for different biodiesel compositions in comparison with conventional diesel engine. Results reported that at full load condition maximum brake power 77 ppm, 47 ppm, 79 ppm and 65 ppm is reported in the case of B25, B50, B75 and B100 biodiesel blends. Whereas in the case of conventional diesel 51 ppm is observed at full load condition which accounts to 10–15 ppm lower than the biodiesel

blends. Hydrocarbon emission increases due to larger ignition delay period resulting in incomplete combustion even though higher temperature is maintained in combustion chamber during compression stroke. However, at full loads, hydrocarbon emission reduces resulting in complete combustion as ignition delay period is shorter Raslavicius [17]. It can be concluded that hydrocarbon emissions are lesser in case of B50 and B25 in comparison with b75 and B100 biodiesel blends. Simultaneously, in-cylinder fluid flow characteristics and combustion chamber geometry also play predominant role on the effect of hydrocarbon emissions.

5.4 Nitric oxide emission (NO_x)

Figure 14 represents the nitric oxide formation at different brake power and load for different biodiesel blends in comparison with conventional diesel fuel. NO_x particles are usually developed due to the variation in combustion pressure resulting in the rise of in-cylinder temperature. Results reported states the increase in the load results in rise of NO_x emission. At full load condition, 79 ppm, 95 ppm, 105 ppm and 160 ppm are observed in the case of B25, B50, B75 and B100 biodiesel blends. It is reported that the NO_x particles for conventional diesel are 130 ppm at full load condition which is 51, 35 and 25 ppm greater than the biodiesel blends. It can be concluded from the aforementioned discussion that when compared to conventional diesel NO_x emission is less for biodiesel fuel because of the presence of oxygen and higher cylinder temperature in the combustion chamber. In the open literature's researchers reported that, at low loads, the formation of NO_x was comparatively low in contrast to full load condition Ye, Abu Lei and Lapuerta [31–33]. However, at low loads rise in ignition delay results in reduction in peak pressure followed by low in-cylinder temperature is reported Raka and Imran [34]. Hence, concluded that at

Fig. 15 Load versus brake specific fuel consumption with 10% EGR and without EGR

Fig. 16 Load versus brake specific energy consumption with 10% EGR and without EGR

full load condition NO_x emission also increases because of low Cetane value, as well as longer ignition delay in case of biodiesel blends.

6 Engine performance analysis with 10% exhaust gas recirculates (EGR)

Engine performance is carried out with 10% EGR for different biodiesel compositions in comparison with conventional diesel. Initially, experiments are done on various loads to create basic data. The engine was stabilised before taking all the readings. Analysis has been carried out on different biodiesel blends (i.e. B25, B50, B75 and B100), conventional diesel by 10% EGR in comparison with without EGR. Tests are carried out on four stroke single-cylinder DI diesel engine.

6.1 Brake specific fuel consumption (BSFC)

Figure 15 represents specific fuel consumption variation for different blends in comparison with pure diesel with 10% EGR and without EGR is discussed. Results reported that an increase in the load specific fuel consumption is reduced in case of 10% EGR in comparison with without EGR. At full load condition, specific fuel consumption without EGR was found to be 0.2985 kg/kWh for B25 and 0.3067 kg/kWh for B75 and B50, 0.2998 kg/kWh for B100 and 0.31 kg/kWh for diesel. Whereas with EGR 0.36, 0.36, 0.34, 0.36, and 0.34 kg/kWh is reported in case of conventional diesel and various blends. We observed that for 10% EGR, specific fuel consumption increased in both the conventional diesel and biodiesel blends. However, slightly higher values are reported in the case of biodiesel because

of density, low calorific value, higher viscosity and boiling point.

6.2 Brake specific energy consumption

Figure 16 represents the variation of brake specific energy consumption for different biodiesel blends in comparison with conventional diesel with 10% EGR and without EGR is discussed. Results reported that with a rise in the load, brake specific energy consumption is reduced in case of 10% EGR in comparison with without EGR. At peak, BSEC is found to be 14,459.74, 14,072.96, 12,842.43, 12,432.83 and 15,419.12 kJ/kWh, respectively, in case of B25, B50, B75, B100 and D100 without EGR. Simultaneously, at full load values of diesel and other biodiesel blends D100, B100, B75, B50, B25 with EGR are obtained 15,843.34, 12,962.92, 14,255.92, 14,048.66, and 15,101.59 kJ/kWh. Results reported that brake specific energy consumption is increasing with EGR compare to without EGR.

7 Conclusion

Biodiesel was extracted from raw Kusum oil by implementing transesterification method under different operating conditions. FT-IR test was performed to identify the thermophysical characteristics of sample biodiesel. Various proportions of Kusum oil blends were prepared based on volumetric condition. Tests were carried out on single-cylinder diesel engine with conventional diesel as the base line fuel. Influence of biodiesel blends at variable load and fuel injection pressure is considered as input parameters to examine various characteristics of performance and emission.

- FT-IR spectrum of biodiesel in which the first peak is reported between 1000 and 1300 cm^{-1} . The second peak is reported between 1700 and 1800 cm^{-1} , where a predominately larger quantity of biodiesel is present with a maximum peak where absorption of the carbonyl is maximum.
- Due to lesser density, absolute biodiesel blends have the characteristics of quality mixing leads to better atomisation of working fluid.
- In case of biodiesel blends, as larger amount of biodiesel resulting in greater mixing efficiency and lesser ignition duration resulting in increase in BTE.
- Rise in the composition of Kusum oil leads to decreases in the calorific value and an increase in the mass flow rate for obtaining similar operating parameters.
- At full load condition, NO_x emission also increases because of the low Cetane value, longer ignition delay in case of biodiesel blends.
- Using EGR with 10% on CI Engine, the results are slightly increasing of BTE, BSFC, BSEC, CO, CO_2 , HC and decreasing NO_x .

From aforementioned findings, it is concluded that biodiesel can be blended with diesel and can be used as an alternative fuel for diesel engine and 25 and 50 BED blends can be used safely without modification in the diesel engine. For improving the yield of ethanol (from WH), more efficient organisms can be used for fermentation and to get more reliable and stable biodiesel blend, and some other efficient blending reagent and cosolvent can be used for further study.

Compliance with ethical standards

Conflict of interest The author declared that they have no conflict of interest.

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