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Research paper

Experimental investigation of the effect of injection pressure on performance and emission of DI Diesel engine fueled with scum oil methyl ester blends

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Abstract

In the present experimental study dairy wash water was used for the production of scum oil methyl ester as alternate fuel for CI engine which satisfy all the characteristics of the conventional diesel. Dairy waste Scum was converted into bio-diesel by using two stage transesterification processes. First stage acid catalyst esterification process was used in which concentrated H_2SO_4 was 10 ml, methanol 250 ml, temperature 60°C and reaction time 60 minutes, in second stage base catalyst transesterification process methanol to oil molar ratio of 7.5:1, catalyst concentration of 0.961 wt%, reaction time 49.529 min and temperature 63.46°C was used in which 850 ml of biodiesel was obtained from one liter crude scum oil. Produced Scum oil methyl ester was blend with diesel with various proportions such as [B10, B20, B30, B40 and B100] was analyzed and compared with pure diesel. Prepared test samples were subjected to diesel engine and several tests have been carried out to examine properties, performance, combustion and emission characteristic with varying injection pressure [180, 200 and 220 bar]. Performance and emission characteristic was carried out on diesel engine to determined BSFC, break thermal efficiency and exhaust gas temperature and emission characteristics like CO, CO_2, NO_x, O_2, smoke opacity and HC. The obtained results were compared with diesel and blends of scum oil methyl ester at the three injection pressure. From the overall results obtained for all the blends of diesel and diesel at three operating injection pressure it can be concluded that B20 samples can be used as an alternate fuel at an injection pressure of 200 bar in to CI engine without any modification. This sample will give better performance and less exhaust emission than any other blends. The performance and emission characteristics of B20 samples will remains same as D100.

Keywords: *scum of milk, Trans esterification, injection pressure, performance, combustion, emission.*

1. Introduction

Diesel fuel is the singles largest source to power vehicles both in transportation and agriculture sectors. For many decades, the world's energy production has relied mainly on non-renewable crude oil derived from fossil fuel. The availability of fossil fuel is limited, out of which about 80 per cent is estimated to be consumed for energy and transportation. Due to increase in consumption of fossil fuel since few years, a strong threat to clean environment is being posed as the burning of fossil fuel is associated with emission like CO, CO_2, O_2, HC NO_X, and particular matter. Which are major causes of air pollution? This combination of increasing need and diminishing supply constitutes the energy crisis. The world urgently needs a clean energy source that is able to meet our requirements. Bio fuels are the most suitable fuel which can be produced from edible and non-edible oil. Liquid fuels from renewable resources are biodegradable and inexhaustible. In this regard vegetable oils having their physical and combustible characteristics close to diesel fuel may stand as immediate candidate substitute for alternative fuel to reduce its dependence on imports. Various researchers have conducted experiments to study the performance and emission characteristics of diesel engine when vegetable oils, blends of vegetable oil and its derivatives are used as fuel and it has been found to be economical and competitive compared to standard diesel [1]

P. Siva kumara et al. [2] studied bio-diesel production by alkali catalyzed transesterification of dairy waste scum. The yield of bio-diesel reached 96.7 per cent when 1.2 wt. per cent of Potassium Hydroxide, reaction temperature of 75°C, 30 minute of time and 6:1 methanol oil ratio at 350 RPM. K V Yathish et al. [3] conducted optimization test for biodiesel production from mixed oil (Karanja &Dairy waste Scum oil) using homogeneous catalyst. The optimum conditions for mixed oil biodiesel production were a catalyst concentration of 1.0 per cent w/w of oil, a reaction temperature of 70°C, a reaction time of 30minutes 6:1 methanol to oil molar ratio at 400rpm. The methyl ester content under these optimum conditions was 95.10 %. Ravichandra V Koti1 et al. [4] investigated the performance and emission characteristics of a direct injection diesel engine using safflower oil and milk scum oil as a biodiesel. The HC, CO and CO_2 emissions were found to be less than that of neat diesel fuel except NOx. Break Thermal Efficiency of biodiesel and its blends was found to be less than diesel fuel, Exhaust Gas Temperature, Break Specific Fuel Consumption for biodiesel and its blends were found to be higher than diesel fuel. M.V. Mallikarjun et al [5] studied NOx emission control techniques

when ci engine is fuelled with blends of Mahua methyl esters and diesel. The nitrogen oxide (NOx) emissions are high and it is necessary to reduce this emission before using methyl ester as a fuel for diesel engines. In this work, retardation of injection timing and exhaust gas recirculation (EGR) are used to reduce the same. However UBHC, CO and particulate emissions increase when retarding the injection timing.
Honnegowda et al. [6] studied the effect of injection pressures on the performance and emission characteristics of c.i engine with cotton seed oil methyl ester. The effect of injection pressure on the performance and emission was studied at three different test pressures such as 180 bar, 200 bar and 220 bar. The results showed a better performance at an injection pressure of 200 bar. C.V. Subba Reddy et al. [7] studied the effect of injection pressure on the performance and emission characteristics for various biodiesel blends of 0BD, 10BD, 20BD, 30BD and 100BD at six different test pressures of 170, 180, 190, 200, 210 and 220 bar. The experimental investigations reveal that the better performance and emission characteristics among the biodiesel blends are obtained at injection pressure of 200 bar with 20BD of cotton seed oil methyl ester. Nagarhalli M.V et al. [8] conducted experiment at different injection pressure to determine the emission and performance characteristics of Karanja biodiesel and its blends in C.I. Engine. The results indicate that the CO emissions were almost constant, HC emissions decreased by up to 25 per cent for B40, NOx emissions decreased by 30.39 per cent for biodiesel blends. The performance of the engine improved at a biodiesel blend of 40 per cent and an injection pressure of 200 bar. Orkun Ozener et al. [9] studied the effect of soybean methyl ester on DI diesel engine. The experimental results, showed that, relative to diesel, biodiesel had a 1–4% decrease in the torque and an approximately 2–9% increase in the brake-specific fuel consumption (BSFC) due to the lower heating value (LHV) of the biodiesel. However, biodiesel significantly reduced carbon monoxide (CO) (28–46%) and unburned total hydrocarbons (THCs), while the nitric oxides (NOx) (6.95–17.62%) and carbon dioxide (CO2) emissions increased slightly 1.46–5.03%. Ozer Can et al. [10] conducted experimental study on canola biodiesel blends in which heat release rate decreases with reduction of premixed combustion fraction. BSFC increased up to 6.56% and BTE reduced up to 4.2% with rise in canola biodiesel ratio to 20% at the high load. The canola biodiesel blends also resulted in higher NOx emissions of 8.9% as well as lower smoke, CO and UHC but slightly higher CO_2 emissions for all loads.

P.K. Sahoo et al. [11] were conducted combustion analysis such as peak pressure, time of occurrence of peak pressure, heat release rate and ignition delay of Jatropha, Karanja and Polanga based biodiesel as fuel in a diesel engine. Polanga biodiesel results in maximum peak cylinder pressure and the ignition delays were consistently shorter for neat Jatropha biodiesel, varying between 5.9° and 4.2° crank angles lower than diesel. Similarly, ignition delays were shorter for neat Karanja and Polanga biodiesel when compared with diesel. K. Muralidharan et al. [12] investigated the influence of different compression ratios (18:1, 19:1, 20:1, 21:1 and 22:1) on performance, emission and combustion characteristics using waste cooking oil methyl esters and diesel blends. The performance of the B40 blend is superior when compared with the conventional standard diesel at compression ratio 21. There is slight increase in NOx emission, but it is still comparable with that of standard diesel fuel and is also in the acceptable range. Mohammed et al. [13] Studying the effect of compression ratio on DI engine fueled with waste oil biodiesel blends. Increasing the compression ratio improved the performance and cylinder pressure of the engine and had more benefits with biodiesel than with high pure diesel.

T. Ganapathy et al. [14] investigated the influence of injection timing on performance, combustion and emission characteristics of Jatropha biodiesel. The best injection timing for JOME operation with minimum BSFC, CO, HC and smoke and with maximum BTE, P_{max} and HRR_{max} is found to be 340 CAD. Nevertheless, minimum NO emission yielded an optimum injection timing of 350 CAD. Therefore a proper injection timing tuning process can lead to significant benefits in terms of performance and emissions, when the diesel engine is operated with Jatropha biodiesel.

Most of the studies are conducted in different types of engines with bio diesel prepared from different oils. The effect of parameters on the performance of the engine with emission characteristics and combustion characteristics of the bio diesel has been emphasized in many studies [15-18]. The effect of varying injection pressure on engine parameters, emission and combustion characteristics have not been studied extensively. Hence this study has been devoted to find suitable injection pressure which gives optimum performance. In this study, the performance (brake power, BSFC) and emissions (CO, CO_2, NOx, UHC, O_2 and smoke opacity) characteristics of a diesel engine were investigated in DI diesel engines at varying injection pressure (180 bar, 200 bar and 220 bar) fuelled with pure diesel and blends of Scum oil methyl ester (B10, B20, B30, B40 & B100).

2. Materials and Methods

2.1 Transesterification procedure:

The obtained scum oil is subjected to free fatty acid test using the base titration technique [19] and found to be 9.36 %. The esterification reaction was carried out for reducing FFA content < 2% at 60-70°C by using methanol and sulfuric acid as catalyst. The esterification reaction was carried out in 500 mL, 3 necks, flat bottom flask equipped with a reflex condenser, thermostat, sampling outlet and mechanical stirrer. 100 mL of preheated oil to a temperature of 60°C of both the sample is taken into a two separate flask. A fixed amount of H_2SO_4 (1% v/v) and methanol (20 mL) is added to start the reaction and allowed for 60 min. After completion of the reaction, mixture was allowed to cool down and transferred to the separating funnel for separation of phases. The bottom layer is a mixture of catalyst and alcohol, the upper layer consisting of esterified sample was separated and washed with distilled water, until remains of catalyst were removed and heated to remove water content. This step led to the reduction of FFA of scum oil 1.51% which then stored for further transesterification reaction. Now 100 mL of esterified oil samples was transferred to the above mentioned reactor setup for transesterification reaction process. A measured amount of catalyst [sodium hydroxide] is thoroughly mixed in known quantity of methanol till it dissolved completely to give Sodium Methoxide were added to the reaction mixture in the reactor. After completion of the reaction, the mixture was transferred into the separating funnel and allowed to settle for about 10 hours. Two distinct layers were formed; the topper layer with yellowish color is methyl ester (biodiesel) and the bottom layer with thick brown color is glycerol. The glycerol was removed and biodiesel was washed with warm distilled water to remove the traces of methanol, the catalyst and residual glycerol. The washing process was repeated until the pH of washing water reached 7 pH value and the obtained methyl ester was dried using magnetic stirrer for about 1 hour at 100°C to evaporate the excess water [20]. To determine biodiesel yield it is always expressed as shown in equation (1). The evaluated properties of diesel fuel and diesel-biodiesel blends have been summarized in Table 1.

$$Biodiesel\ Yield\ (\%) = \frac{Weight\ of\ fatty\ acid\ methyl\ ester\ produced\ (g)}{Weight\ of\ oil\ used\ (g)} \times 100 \quad (eq.\ 1)$$

Table 1: Fuel properties of diesel and biodiesel blends

Property	B10	B20	B30	B40	B100	Diesel
Calorific value kJ/kg	42288.6	42077.2	41865.9	41654.5	40,317.8	42,500
Viscosity cSt	3.75	3.82	3.85	3.87	3.9	3.72
Density kg/m^3	845	851	855	861	870	840
Flash point °C	53.4	62.5	71.7	80.8	136	50
Cetane number	-	-	-	-	58.5	49.7

2.2 Engine Description

The setup consists of single cylinder, four stroke, Diesel engine connected to eddy current type dynamometer for loading. It is provided with necessary instruments for combustion pressure and crank angle measurements. These signals are interfaced to computer through engine indicator for Pθ−PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The setup has standalone panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rota meters are provided for cooling water and calorimeter water flow measurement. The setup enables study of engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Lab view based Engine Performance Analysis software package "Engine soft" is provided for on line performance evaluation.

To evaluate the engine performance, combustion and emission characteristics, the experiments were conducted on a Kirloskar make single cylinder four stroke water cooled, direct injection CI engine fueled with test samples, keeping compression ratio of 17.5:1 as constant for various loads (0%, 20%, 40%, 60% 80 % and 100%) at different injection pressure (180 bar, 220 bar and 220 bar) for the fuel samples of (B10, B20, B30, B40, B100 and diesel). Fig. 1 shows the schematic diagram of engine test rig. The specifications of engine and its baseline operating conditions are tabulated in tables 2. A water cooled piezoelectric transducer mounted on the cylinder head surface measures the cylinder dynamic pressure. The emissions from the engine exhaust such as CO_2, CO, HC O_2 smoke opacity and NOx were measured using AVL DIGAS 444 analyzer as shown in table 3 for its range and uncertainty.

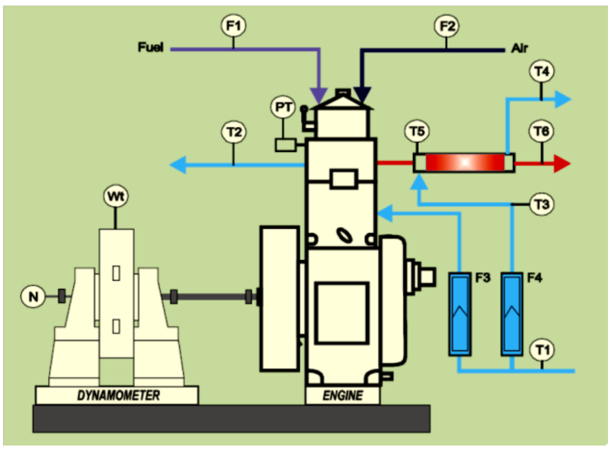


Fig. 1: schematic diagram of engine test rig

Engine cooling water Inlet T1, Engine cooling water Outlet T2, Calorimeter water Inlet T3, Calorimeter water Outlet T4, Calorimeter Exhaust gas in T5, Calorimeter Exhaust gas Out T6, Fuel line F1, Air inlet F2, Engine cooling water 200 lph F3, Calorimeter water 100 lph F4, Pressure transmitter PT, and Crank angle Encoder N.

Table 1: Engine Specification

Engine Make	Kirloskar, Model TV1
Type	1 cylinder, 4 stroke Diesel, water cooled
power	5.2 kW at 1500 rpm
stroke	110 mm
bore	87.5 mm
Displacement	661 cc
Compression ratio	17.5
Dynamometer Type	eddy current, water cooled, Propeller shaft with universal joints
Piezo sensor Range	5000 PSI, with low noise cable
Air box	M S fabricated with orifice meter and manometer
Fuel tank Capacity	15 lit with glass fuel metering column
Crank angle sensor Resolution	1 Deg
Speed	5500 RPM with TDC pulse
Data acquisition device	NI USB-6210, 16-bit, 250kS/s
Piezo powering unit Model	AX-409
Temperature sensor Type	RTD, PT100
Thermocouple	Type K
Thermocouple	I/P - Range 0–100°C, O/P- Range 0–1200°C, 4–20mA
Load indicator Digital	Range 0-50 kg
Load sensor Load cell, type strain gauge,	range 0-50 kg
Fuel flow transmitter DP transmitter	Range 0-500 mm WC
Air flow transmitter Pressure transmitter	Range (-) 250 mm WC
Software	"Engine soft" Engine performance analysis software
Rota meter Engine cooling	40-400 LPH
Calorimeter	25-250 LPH Pump Type Mono block
Overall dimensions	W 2000 x D 2500 x H 1500 mm

Table 3: AVL DI GAS 444 N (Five gas analyzer)

Measurement	Range	Resolution
CO	0-15% Vol	0.0001% Vol
HC	0-20000 ppm Vol	1ppm/10ppm
CO_2	0-20% Vol	0.1% Vol
O_2	0-25% Vol	0.01%Vol
NOx	0-6000 ppm Vol	1 ppm Vol
Opacity(AVL 437C smoke meter)	0-100%	0.1%
Absorption	K Value	0-99-99m^{-1} 0.01m^{-1}

3. Results And Discussion

The use of biodiesel in convention diesel engine results in substantially reduction of unburned hydrocarbon, carbon monoxide and particulate matter (PM) emission. Biodiesel is considered as a clean fuel which has no sulphur, no aroma and has about 10 per cent excess oxygen which helps it to burn completely. Its higher Cetane numbers (CN) improves the ignition quality when blended with diesel. One such alternative fuel was used in the present work is Scum oil methyl ester. From the literature review it was found that the potential of extracting biodiesel from other non-edible oils such as (Neem oil, Mahua oil, waste cooking oil, rubber seed oil, Jatropha oil, Honge oil cotton seed oil, animal fatty etc.) was very less approximately the yield was 60 per cent. But from dairy wash water it was found that upto 85-90 percent yield can be obtained from one kg scum that is 850-900 ml of oil can be extracted.

In this work two stage transesterification process was carried out, in which one stage acid catalyst esterification process and one stage base catalyst transesterification was done for extraction of biodiesel. In acid catalyst esterification process a fixed amount of H_2SO_4 (1% v/v) and methanol (20 mL) is added to start the reaction and allowed for 60 min and in base catalyst transesterification methanol to oil molar ratio of 7.5:1, catalyst concentration of 0.961 wt%, reaction time 49.529 min and temperature 63.46°C was used for complete extraction of biodiesel from scum oil. In the present investigation performance and emission characteristics of various blended fuel such as B10, B20, B30, B40, B100 and diesel was analyzed and obtained results are plotted with graphs as shown below. The performance parameter such as BSFC, Brake thermal efficiency and Exhaust gas Temperature, combustion parameter such as Cylinder combustion pressure and Heat release rate and emission parameter such as CO, CO_2, HC, O_2, NOx and smoke opacity graphs are plotted with respect to varying load at three different injection pressure such as 180, 200 and 220 bar.

3.1 Performance Parameter:

3.1.1 Brake Specific Fuel Consumption (BSFC)

In engine tests, the fuel consumption is measured as flow rate to mass flow per unit time. Specific fuel consumption is the most useful parameter that measured how efficiently an engine is using the fuel supplied to produce work. Lower specific fuel consumption is always desirable for better performance of the engine. The variation of specific fuel consumption with loads for different diesel blends with scum oil methyl ester and for different injection pressure was shown in fig.2. BSFC is the ratio between mass fuel consumption and break effective power and for a given fuel it is inversely proportional to thermal efficiency. BSFC decreases sharply with increase in load for all blend samples of fuels. The main reasons for this was increase in percentage of fuel required to operate the engine is less than the percentage increase in break power, because relatively less portion of heat is lost at higher loads.

From the performance graph plotted for BSFC shows that initially at very lower load BSFC will be very high for all blends. Because of low load lower brake power is developed at high fuel consumption. This is caused due to improper atomization of fuel and also at low load the initial temperature and pressure inside the cylinder will be less which causes incomplete combustion. In case of B30 - B100 the specific fuel consumption is found to be higher than that of diesel at all injection pressure. From the experimental data, BSFC for diesel is 0.311, 0.255, 0.289 kg/kW hr and for B100 0.376, 0.308and 0.355 kg/kW hr at 180, 200 and 220 bar respectively. With increase in injection pressure there was decrease in BSFC for all blend samples. For B20 sample there was 24.1 % decrease in BSFC has taken place at 200 bar pressure than at 180 bar pressure for same blend sample (B20). Also at injection pressure 220 bar it was found that there is increase in BSFC for all blend samples than at 200 bar pressure. This shows that at very high pressure and at very low pressure the performance of CI engine will decrease with increase in BSFC. Hence it can be concluded that at 200 bar pressure for blend sample of B20 gives better results that of diesel, hence which can be used as an alternate fuel for CI engine.

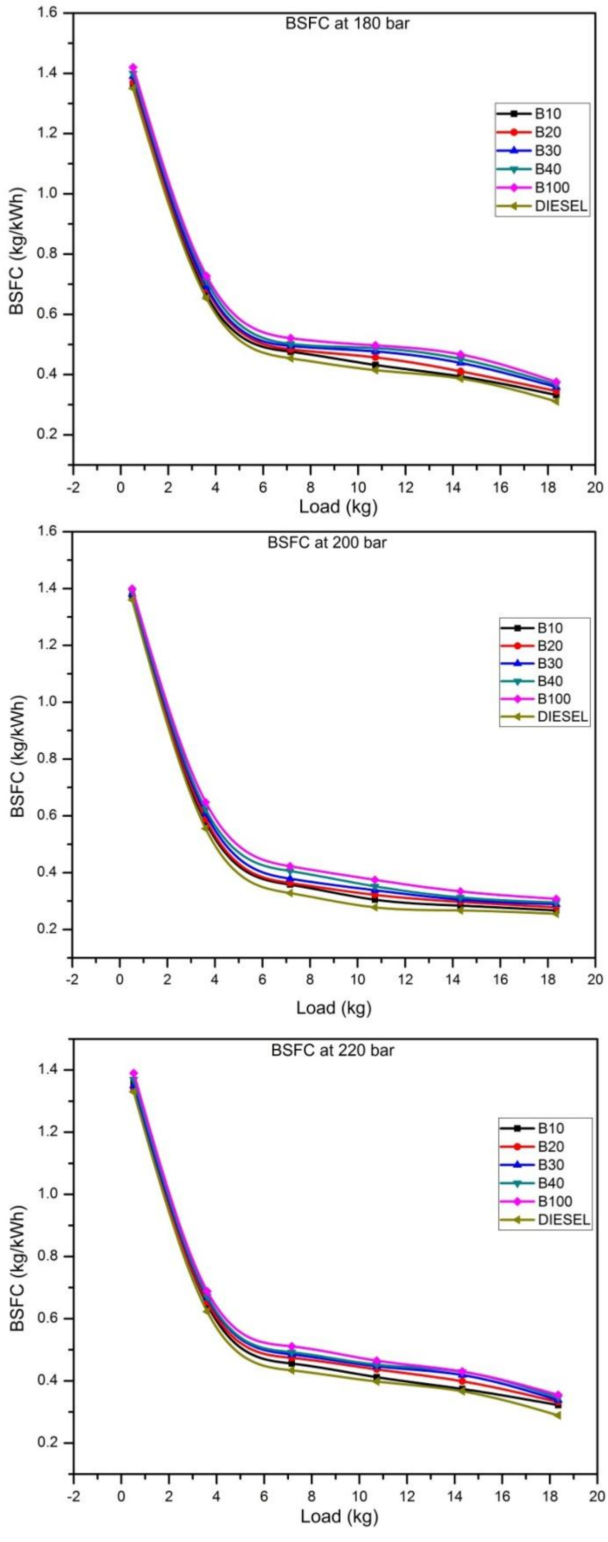


Fig. 2 Effect of load on BSFC of diesel engine fueled with test samples at different Injection pressure (180 bar, 200 bar and 220 bar).

3.1.2 Brake Thermal Efficiency (BTHE)

Thermal efficiency of an engine is defined as the ratio of the output to that of the chemical energy input in the form of fuel supply. BTHE also accounts for combustion efficiency that is the chemical energy of the fuel is not converted into heat energy during combustion process. Variation of BTE with respect to load for different blends of diesel with three different operating injection pressures as shown in fig. 3. With respect to increase in load for all blend samples BTE also increases to maximum and decreases for further increase in the load. With increase in injection pressure BTE for B10, B20, B30 and B40 was 32.77 %, 32.45 %, 31.65 %, 30.98 %, and for diesel 33.21 % this shows that there was average increase in 12.08% at 200 bar pressure. Similarly BTE for B10, B20, B30 and B40 and for diesel 34.87 %, 33.94 %, 33.07 %, 32.5 % and 35 % hence there was average increase in 12.305% at 220 bar pressure. BTE at 180 bar for B10, B20, B30 and B40 will almost remain same as that of diesel. From this data it can be concluded that with increase in injection pressure there was raise in BTE for diesel blends with respect to diesel. This is due to at high injection pressure fuel atomization occurs completely which causes complete combustion. Hence at pressure of 200 bar B20 sample can be used as an alternate fuel directly into diesel engine without any modification instead of conventional diesel.

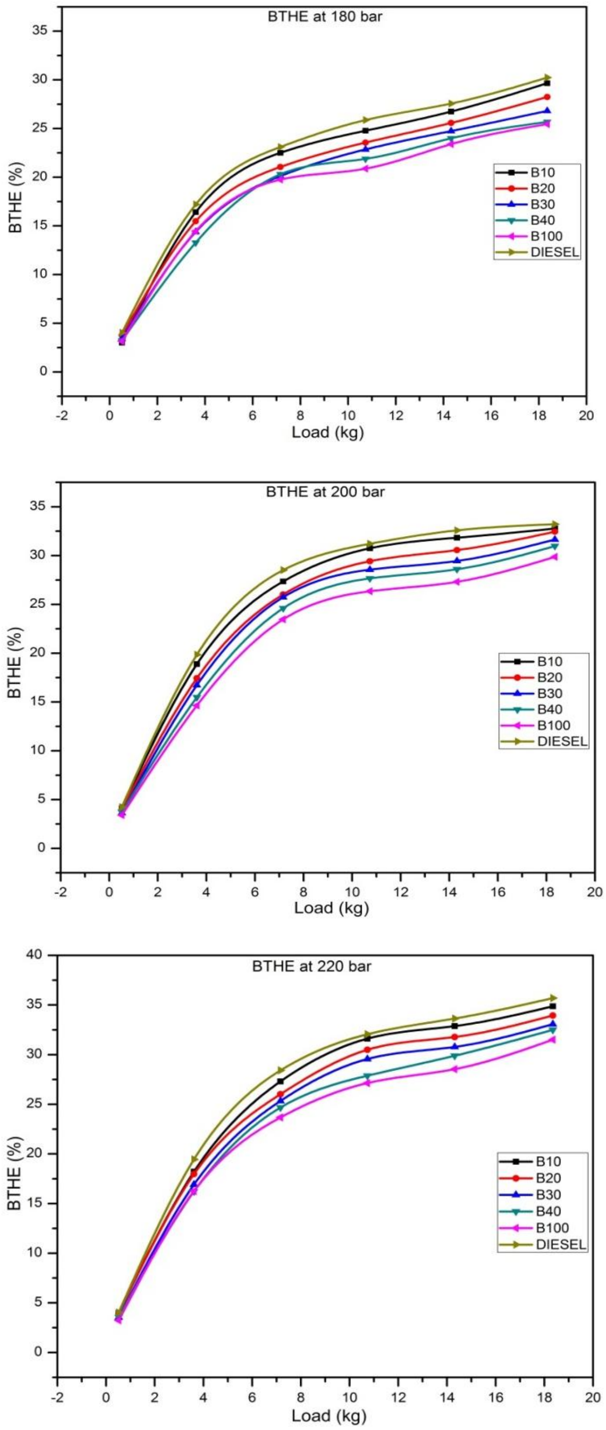


Fig. 3 Effect of load on Brake thermal efficiency of diesel engine fueled with test samples at different Injection pressure (180 bar, 200 bar and 220 bar).

3.1.3 Exhaust Gas Temperature (EGT)

EGT is proportional to the combustion temperature developed inside the engine cylinder through fuel combustion. The variations of exhaust gas temperature for different injection pressure and for different blends are shown in Fig. 4. The result indicates that exhaust gas temperature decreases for different blends when compared to that of diesel. At injection pressure 180 bar the exhaust gas temperature of the blends are higher compared to that of standard diesel. As the injection pressure increases, the exhaust gas temperature of the various blends is lesser than that of diesel. The lower exhaust gas temperature is an indicator of earlier combustion and a lower heating value of the biodiesel fuel; thus, the earlier combustion allows more time and crank angle for the expansion process [21]. At D100, for all loads the EGT is higher than SOME and its blends. Among all the test fuels B100 has lower EGT than that of all other test fuels. The highest temperature obtained is 379.74°C for standard diesel for an injection pressure of 180 bar, whereas the temperature is only 373.95° C for the blend B20. The reason for the reduction in exhaust gas temperature at increased injection pressure is due is due to the low heating value of biodiesel test blends that results in less heat release inside the engine cylinder. Lower exhaust loss may be the possible reason for higher performance [22]. The combustion temperature is an important parameter to explain the formation of NOx inside the engine cylinder.

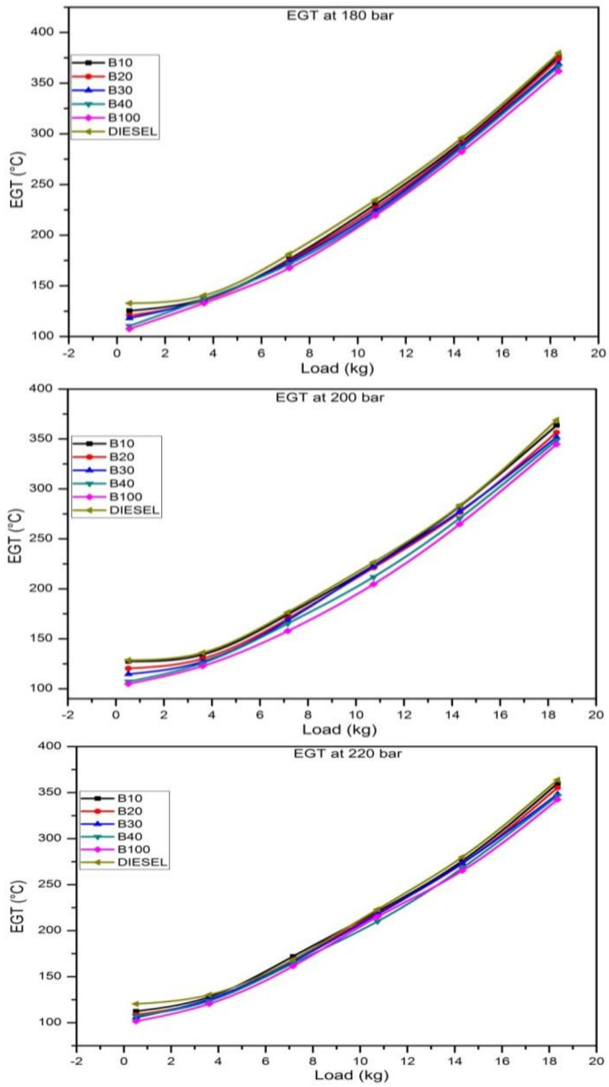
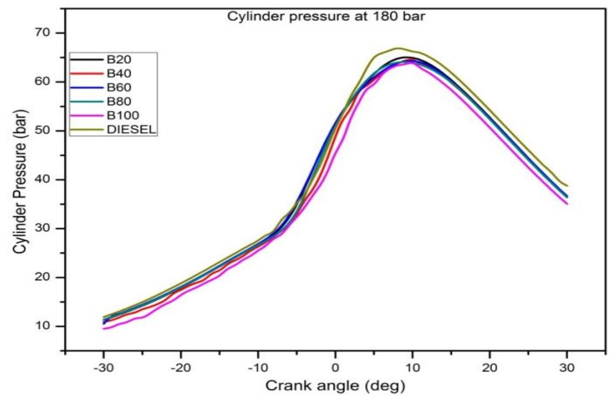


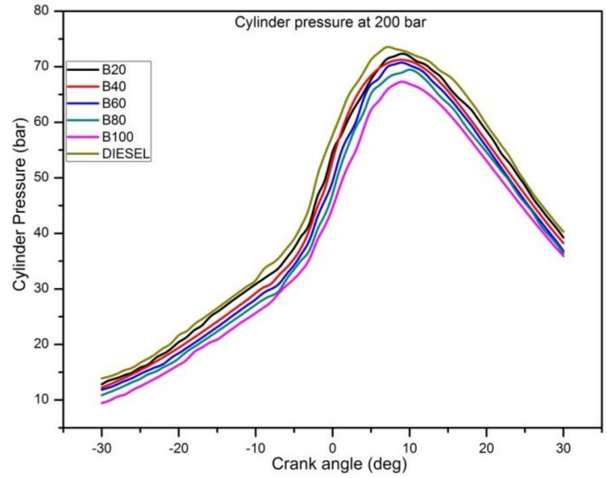
Fig. 4 Effect of load on Exhaust gas temperature of diesel engine fueled with test samples at different Injection pressure (180 bar, 200 bar and 220 bar).

3.2 Combustion characteristic

3.2.1 Cylinder pressure

The variation of combustion pressure with respect to crank angle for different injection pressure and for different blends is shown in Fig. 5. It has been observed from the variation of cylinder pressure for various injection pressure 180 bar, 200 bar and 220 bar that the scum oil blends give lower combustion pressure compared to that of standard diesel due to shorter ignition delay of SOME and may be due to the higher cetane number of the blends. One of the most important parameters in the combustion phenomenon is the ignition delay, which is the time between the start of injection (SOI) and the start of combustion (SOC). The increase in fuel viscosity, particularly for the petroleum-derived fuels, results in poor atomization, slower mixing, increased penetration and reduced cone angle. These phenomena result in a longer ignition delay. However, biodiesel is not derived from crude petroleum, and the opposite trend is seen in the case of biodiesel and their blends. The ignition quality of a fuel is usually characterized by its cetane number, and a higher cetane number generally results in a shorter ignition delay. The maximum peak pressure can also be observed for diesel compared to biodiesel blends. The peak pressure of diesel, B10, B20, B30, B40 and B100 were 74.95, 73.67, 72.82, 72.29, 71.95 and 70.67 bar at crank angle 8°, 8°, 7°, 7°, 8° and 8°of respectively for an injection pressure of 220 bar. The higher combustion pressure obtained due to the rapid and complete combustion of fuel inside the combustion chamber. The combustion pressure for diesel is higher for lower injection pressure and the combustion pressure for blends are higher for higher injection pressure. The maximum rate of increase in pressure is increasing with increase in the injection pressure. The oxygen fortification in the blend due to the addition of bio diesel is the reason for the increased pressure rise. At an injection pressure of 220 bar, maximum pressure rise of the blend B20 is very different from B100.





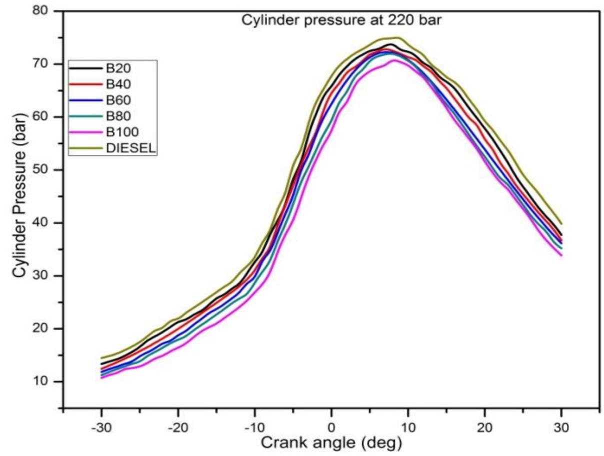
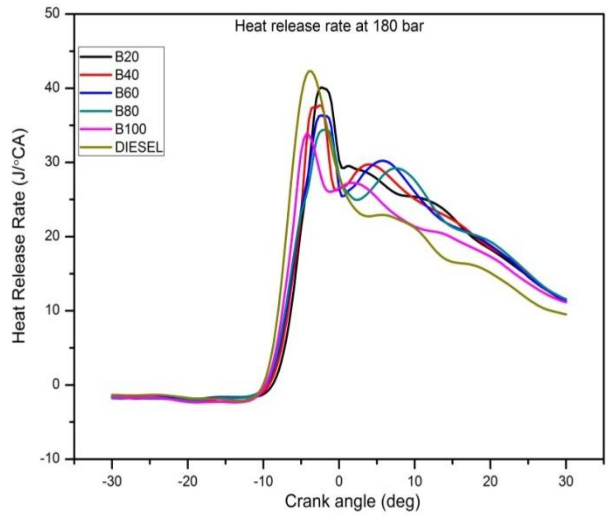


Fig. 5: Variation of combustion pressure with crank angle at full load for different Injection pressure (180 bar, 200 bar and 220 bar).

3.2.2 Heat Release Rate (HRR)

The variation of heat release rate with respect to crank angle for different scum oil blends and different injection pressure 180 bars, 200 bar and 220 bar is given in Fig. 6 respectively. The heat release is analyzed based on the changes in crank angle variation of the cylinder. It has been observed that the heat release rate increases with the higher injection pressure and slightly decreases at lower injection pressure. This may be due to the air entrainment and lower air/fuel mixing rate and effect of viscosity of the blends. The heat release rate of standard diesel is higher than oil blend due to its reduced viscosity and better spray formation. The heat release rate of scum oil blends decreases compared to diesel for increase in injection pressure. This may be due to the reduction in viscosity and good spray formation with increase in injection pressure in the engine cylinder. The mass fraction burnt of blends is slightly higher at lower injection pressure and closely follows the standard diesel at higher injection pressure. Due to the oxygen content of the blend, combustion is sustained in the diffusive combustion phase. The engine operates in rich mixture and it reaches stoichiometric region at higher injection pressure. More fuel is accumulated in the combustion phase and it causes rapid heat release. The maximum HRR at injection pressure of 220 bar was obtained for diesel (47.97 J/°CA) followed by B10 (45.8 J/°CA), B20 (44.12 J/°CA), B30 (41.85 J/°CA), B40 (41.78 J/°CA) and B100 (41.23 J/°CA). The longer ignition delay for diesel results in more accumulation of fuel inside the cylinder, low viscosity and density of diesel leads to better mixing and atomization of fuel compared to biodiesel blends that results in high HRR.



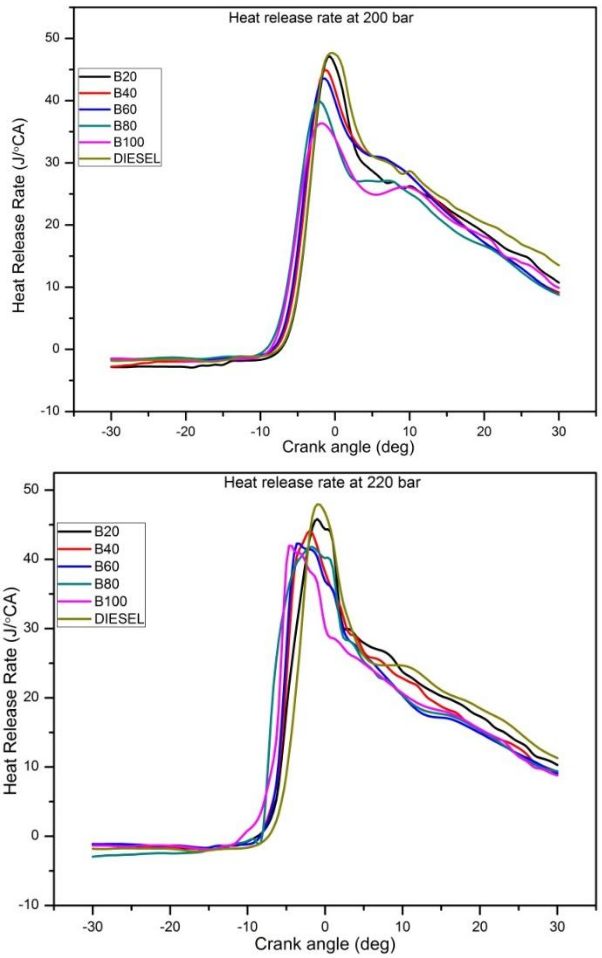


Fig. 6 Variation of heat release rate with crank angle at full load for different Injection pressure (180 bar, 200 bar and 220 bar).

3.3 Characterization of Exhaust Gas Emission

Engine emission can be divided into two groups, regulated and unregulated emission. Regulated emissions are carbon monoxide (CO), nitrogen oxides (NOx) and un-burned fuel or partly oxidized hydrocarbons (HC). The levels of these emissions are specified by legislations. Unregulated emission include polycyclic aromatic hydrocarbons (PAHs), methane, aldehydes, carbon dioxide (CO_2) other trace organic emission and carbon deposits. In diesel engine during combustion process exhausts gases are released to the atmosphere through smoke pipe. In this exhaust gases it was found that some percentage of CO, CO_2, HC and NOx gases are released to the atmosphere which causes the greenhouse effect and also pollute the surrounding atmosphere. Hence in the present investigation exhaust gas emission was determined using five gas calorimeter. Variation of CO, CO_2, O_2, HC, NOx and smoke opacity gases with respect load for different blend samples are plotted at three operating pressures (OP) as shown below.

3.3.1 Carbon monoxide emission (CO)

Carbon monoxide occurs only in the engine exhaust and it is the product of incomplete combustion due to insufficient amount of air in the air fuel mixture or insufficient time in the cycle for completion of combustion. Carbon monoxide is colour less, odorless, poisonous gas which must be restricted from the exhaust gases emitting from the engine. Carbon monoxide emissions are high when the engine is idling and reaches minimum values during declaration. They are lowest during acceleration and at steady speed. When throttle valve is closed it will reduces the oxygen supply to engine is the main cause of carbon monoxide, so deceleration from high speed will produce high carbon monoxide in the exhaust gases.

Variation of CO gases with respect to load at different blends are plotted for three operating pressures 180, 200and 220 bar (OP) as shown fig. 7. With increase in load it was found that there was increase in CO emission for all the blends. When percentage of biodiesel increases with diesel, emission of CO will decrease with increase in load and injection pressure than conventional diesel. For D100 CO emission was 0.22%, 0.08% and 0.07% for B20 0.19%, 0.05% and 0.07% and for B100 0.16%, 0.07% and 0.052% at 180, 200 and 220 bar respectively. From the experimental data it was found that there was 20-50 per cent reduction in CO emission with increase in injection pressure from 180 bar to 200 bar. This is caused because of percentage of oxygen percent in bio-fuel is more than in conventional diesel and also with high injection pressure complete mixing of fuel particles takes place with air which leads to complete combustion. For B20 blend sample, CO emission was very much less than diesel and also with other blends for all the three operating pressure.

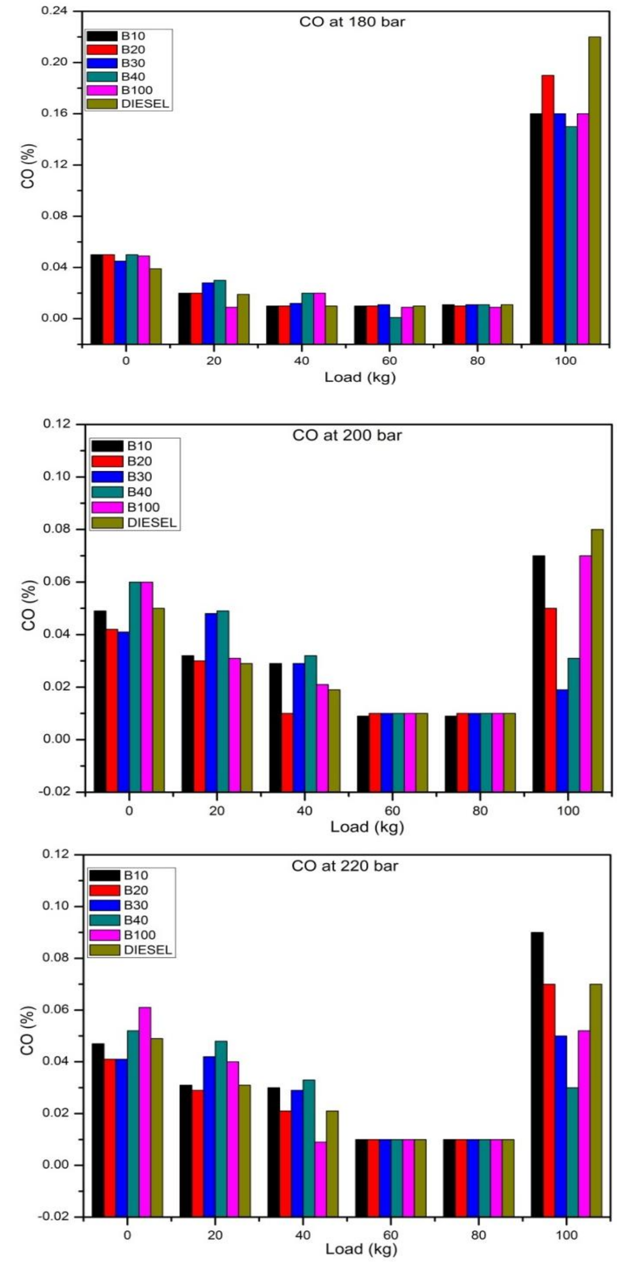


Fig. 7 Variation of CO with increasing load for different blend samples at different Injection pressure (180 bar, 200 bar and 220 bar).

3.3.2 Carbon-dioxide emission (CO_2)

Carbon-dioxide emissions are released to the atmosphere when fuel is completely burned, in the engine. The other significant emissions from diesel engines are the CO_2 emissions, which can contribute to serious public health problems and play a major role in ozone formation [23]. Variation of CO_2 gases with respect to load at different blends are plotted for three operating pressures 180, 200 and 220 bar (OP) as shown fig. 8. With increase in load it was found that there is increase in CO_2 emission and reaches maximum at full load for all the blend samples. For D100 CO_2 emission was 4.83 %, 6.56 % and 8.34 % for B20 4.42 %, 6.23 % and 8.14 % and for B100 4.31%, 5.59 % and 7.82 % at 180, 200 and 220 bar respectively. From the experimental data it was found that there was 8-10 per cent reduction in CO_2 emission for all the blend samples with respect to diesel. This is caused because of percentage of oxygen percent in bio-fuel is more than in conventional diesel and also with high injection pressure complete mixing of fuel particles takes place with air which leads to complete combustion. For B20 blend sample, CO_2 emission was very much less than diesel and also with other blends for all the three operating pressure.

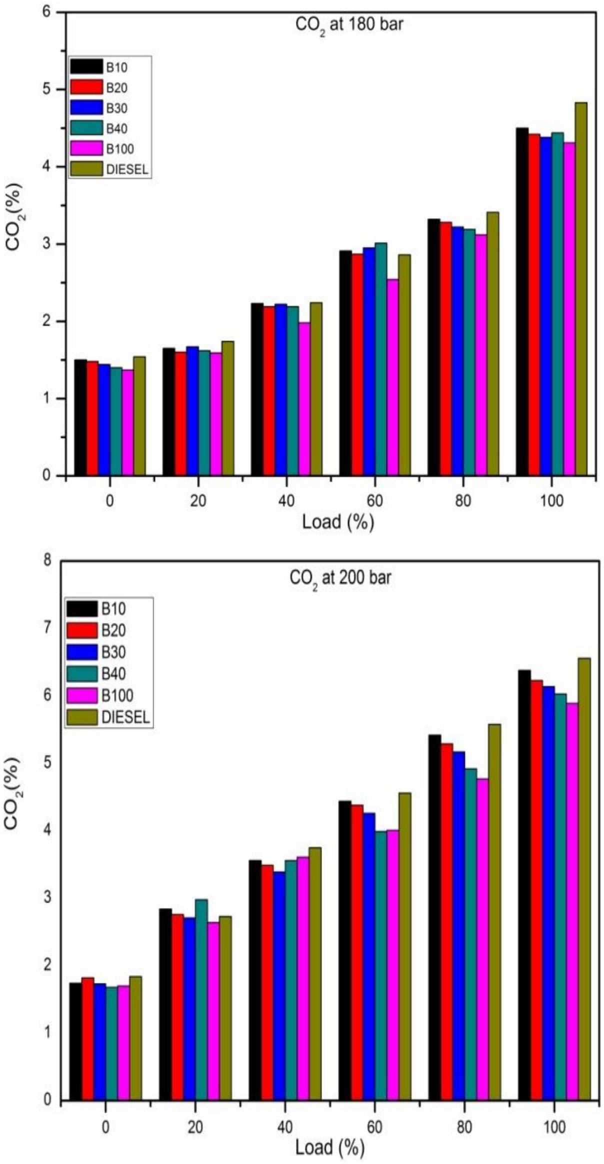


Fig. 8: Variation of CO_2 with increasing load for different blend samples s at different Injection pressure (180 bar, 200 bar and 220 bar).

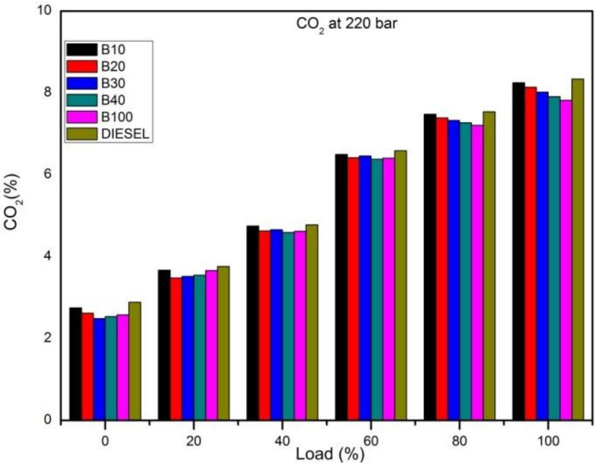
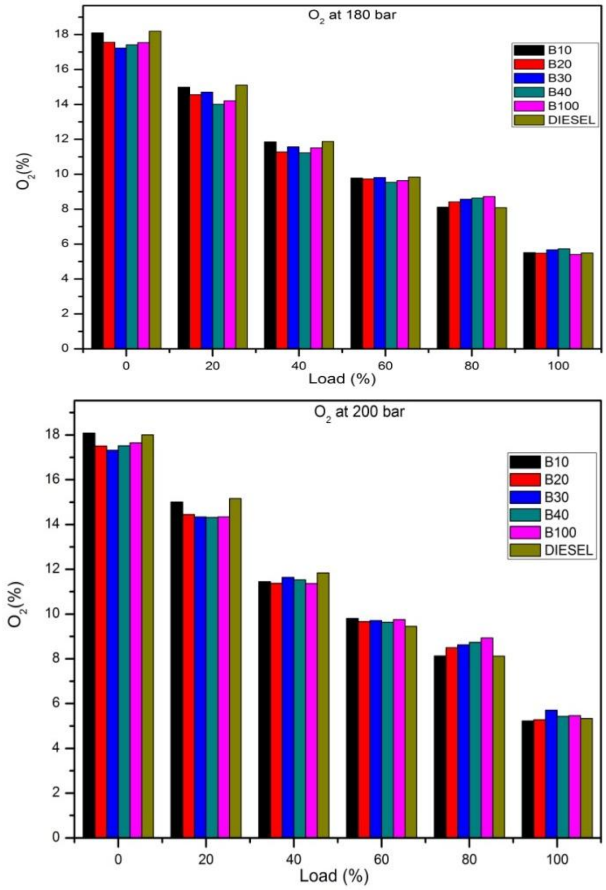


Fig. 8 Variation of CO_2 with increasing load for different blend samples at different Injection pressure (180 bar, 200 bar and 220 bar).

3.3.3 Oxygen emission (O_2)

Variation of O_2 gases with respect load at different blends are plotted for three operating pressures 180, 200 and 220 bar (OP) as shown in fig.9. With increase in load it was found that there was decrease in O_2 emission for all the blends at all the injection pressure. When percentage of biodiesel increases with diesel, emission of O_2 will decrease with increase in load and injection pressure than conventional diesel. For D100 O_2 emission was 5.67%, 5.69% and 5.41% and for B25 5.49%, 5.34% and 5.41% and for B100 5.41%, 5.46% and 5.81% at 180, 200 and 220 bar respectively. From the experimental data it was found that there was 2-5 per cent reduction in O_2 emission with increase in injection pressure from 180 bar to 200 bar. For B20 blend sample, O_2 emission was very much less than diesel and also with other blends for all the three operating pressure.



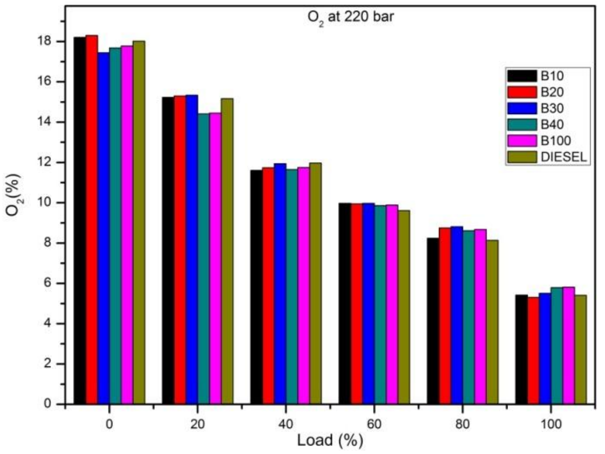


Fig. 9 Variation of O_2 with increasing load for different blend samples at different Injection pressure (180 bar, 200 bar and 220 bar).

3.3.4 Hydrocarbons emission (HC)

Hydrocarbons are more appropriately organic emission, are the direct results of incomplete combustion of the hydrocarbons fuel. The level of unburned Hydrocarbons (UHC) in the exhaust gases is generally specified in terms of the total hydrocarbon concentration expressed in parts per million carbon atoms. The total hydrocarbon emission is a useful measure of combustion inefficiency it is not necessarily a significant index a pollutant emission. Most of the HC is caused by unburned fuel-air mixture, whereas the other sources are the engine lubricants and incomplete combustion. HC are a serious problem at low load in CI engines. At a low loads, the fuel is less adopt to impinge on the surface, because of poor fuel distribution, large amount of excess air and low exhaust temperature, lean fuel air mixture may survive to escape into the exhaust as HC. Fuel composition was significantly influence the composition and magnitude of the organic emission. Fuels containing high proportions of aromatics and olefins produce relatively higher concentration of reactive hydrocarbons. However many of the organic compounds found in the exhaust are not present in the fuel indicating that significant Pyrolysis and synthesis occurs during the combustion process.

The variation of HC with respect to the load at different blends for three different injection pressure (180, 200 and 220 bar) as shown in fig.10. Initially at low load HC emission will be very less, with increase in load, increase in HC emission takes place for all the blend samples and at all the injection pressure. As injection pressure increases HC emission will decrease, this is due to when fuel is injected into the cylinder, complete atomization of fuel occurs which completely mixes with the air and forms homogeneous mixture causes complete combustion in the cylinder. For D100 HC emission is 68, 62 and 54 PPM and for B100 HC emission is 55, 50 and 343 PPM and average value of HC emission from all the blends of diesel is 61, 50 and 47 PPM at the three operating injection pressure 180, 200 and 220 bar respectively. For B20 sample HC emission was 63, 56 and 48 PPM, it was found that there was reduction in 5, 6 and 6 PPM of HC emission when compared to diesel at three operating injection pressure respectively. From the graphs it can be concluded that with increase in blending percentage with diesel it was found that there was decrease in HC emission, this is due to more amount of saturated fatty acid (paraffin) are present in bio fuel than unsaturated fatty acid (olefins and aromatics). But with higher blend percentage of biodiesel in diesel it will reduce the performance of the engine; hence B20 sample is the most feasible as alternate fuel for CI engine which satisfies most of the diesel parameters.

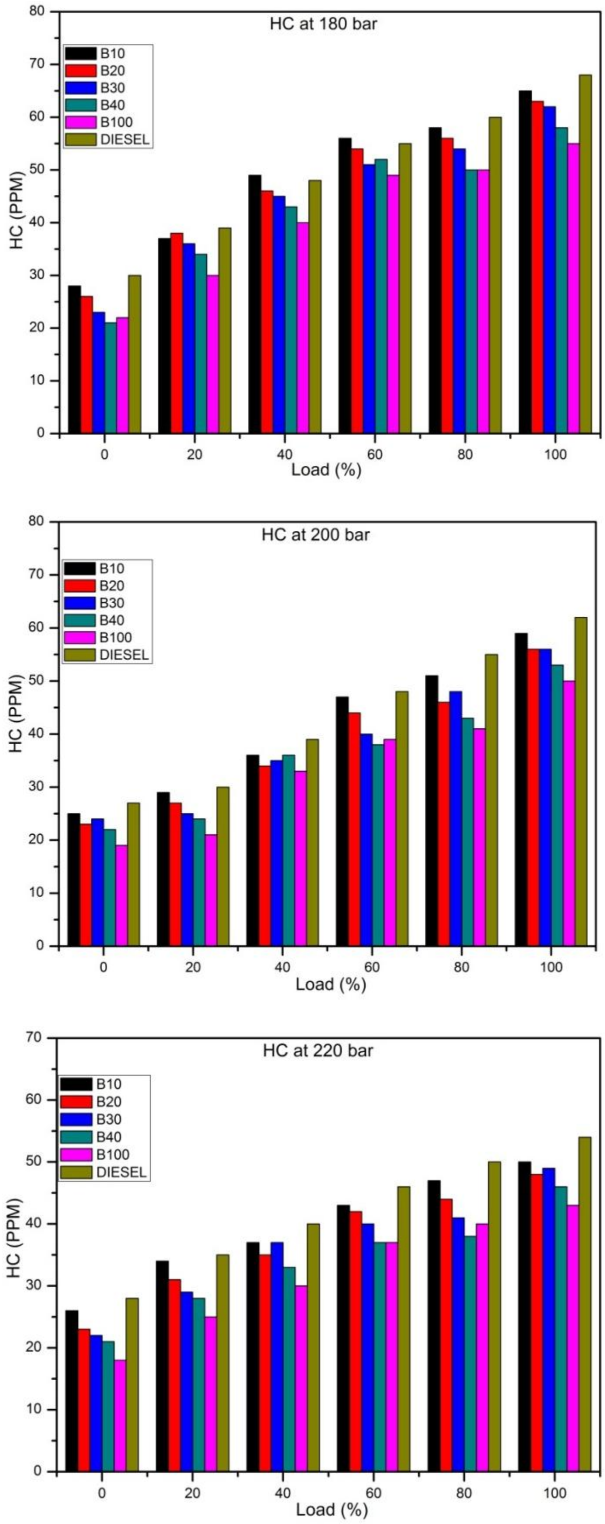
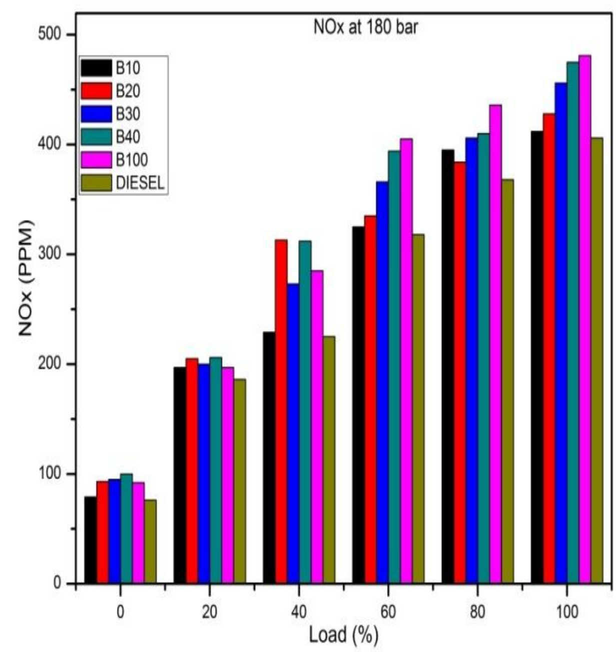


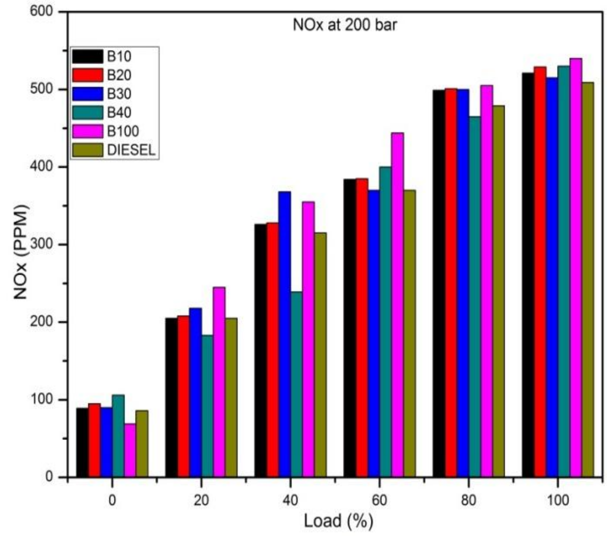
Fig. 10 Variation of HC with increasing load for different blend samples at different Injection pressure (180 bar, 200 bar and 220 bar).

3.3.5 Nitrogen Oxides Emission (NOx)

The most troublesome emission from CI engine are NOx emission the oxides of nitrogen in the exhaust emission contain nitric oxide (NO) and nitrogen dioxide (NO_x). The formation of NOx is highly dependent on cylinder temperature, the oxygen concentration and residence time for the reaction to take place. In a diesel engine, the fuel distribution is non-uniform. The pollutant formation process is strongly dependent upon the changes in the fuel with time because of mixing. The oxidation of nitrogen form in the high temperature region, which is non-uniform and the formations rates are highest in the regions closest to the stoichiometric region. When nitric oxide (NO) and nitrogen dioxide (NO_2) are usually grouped together as NOx emissions, NO is the predominant oxide of the nitrogen produces inside the engine cylinder. The principle source of NO is the oxidation of atmospheric nitrogen. Higher the combustion reaction temperature the more diatomic nitrogen, N_2 will disassociate to monatomic nitrogen, N and more NOx will be formed and at very low temperature very little NOx is created. Although maximum flame temperature will occur at stoichiometric air-fuel ratio (A/F=1) the maximum NOx is formed at a slightly lean equivalence ratio of about 0.95. At this condition flame temperature is very high, and in addition there is excess oxygen that can combine with nitrogen to from various oxides. The formation of NOx also depends on pressure, air-fuel ratio and combustion duration plays a significant role in NOx formation within the cylinder.

The variation of NOx with respect to the load at different blends for three different injection pressure (180, 200 and 220 bar) are as shown in fig.11. NOx emission will increase with increase in load and injection pressure. At full load NOx emission was maximum for all the blends and at all the injection pressure. With increase in blend proportion to diesel NOx emission will also increase, this is due to at high blend mixture percentage of oxygen present in biodiesel is more. This excess oxygen reacts with nitrogen at peak temperature during combustion process which causes the NOx emission. For D100 NOx emission was 406, 509 and 540 PPM and for B100 481, 540 and 595 PPM and also the average NOx emission from all the blends of biodiesel are 451, 527 and 576 PPM at maximum load and for all the three injection pressure respectively. For B20 NOx emission was found to be 428, 529 and 576 PPM at maximum load for all the three injecting pressure 180, 200 and 220 bar respectively. It was found that there was raise in NOx emission by 22, 20 and 36 PPM from B20 to D100. The major problem when blends of biodiesel were used as fuel in CI engine, it will produce more amount of NOx emission than the diesel fuel. But the difference amount of NOx emission between B20 and D100 was very less; hence this amount of NOx emission will not affect much on environment and also on engine performance. Because of this B20 blend sample can be used as an alternate fuel for CI engine.





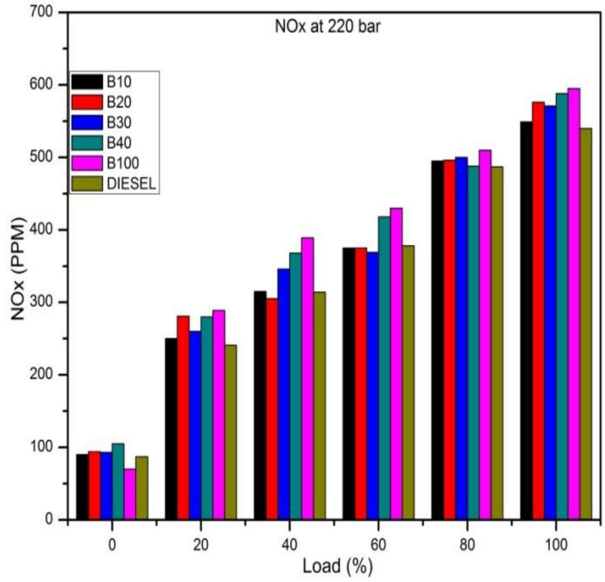


Fig. 11 Variation of NOx with increasing load for different blend samples at different Injection pressure (180 bar, 200 bar and 220 bar).

3.3.6 Smoke Opacity

The variation of smoke opacity emissions with load at different injection pressure is presented in fig. 12. It is clear that the smoke emissions of biodiesel blends are lower than that of diesel and decreases with increase in blend ratio. This is due to poor volatility and higher viscosity of biodiesel which causes improper mixing of fuel droplets with air. This decrease in smoke emission by advancing the injection pressure is due to the dominance of premixed combustion phase. At the time of start of combustion, the accumulated fuel is more due to advanced injection pressure and therefore premixed combustion stage is longer. The fuel air mixture preparation is good in this phase due to longer ignition delay which results in better combustion and low smoke emission. At injection pressure of 220 bar the smoke opacity of diesel is 72.8 %, and for other blend samples is as follows 63.9 %, 61.67%, 57.3 %, 55.16 % and 53.23 % for B10 B20 B30 B40 and B100 respectively. With increase in injection pressure smoke opacity will decrease for all the test samples. For B20 the smoke opacity was found to be less when compared to diesel at all the injection pressure, hence it can be used as alternative fuel for diesel engine.

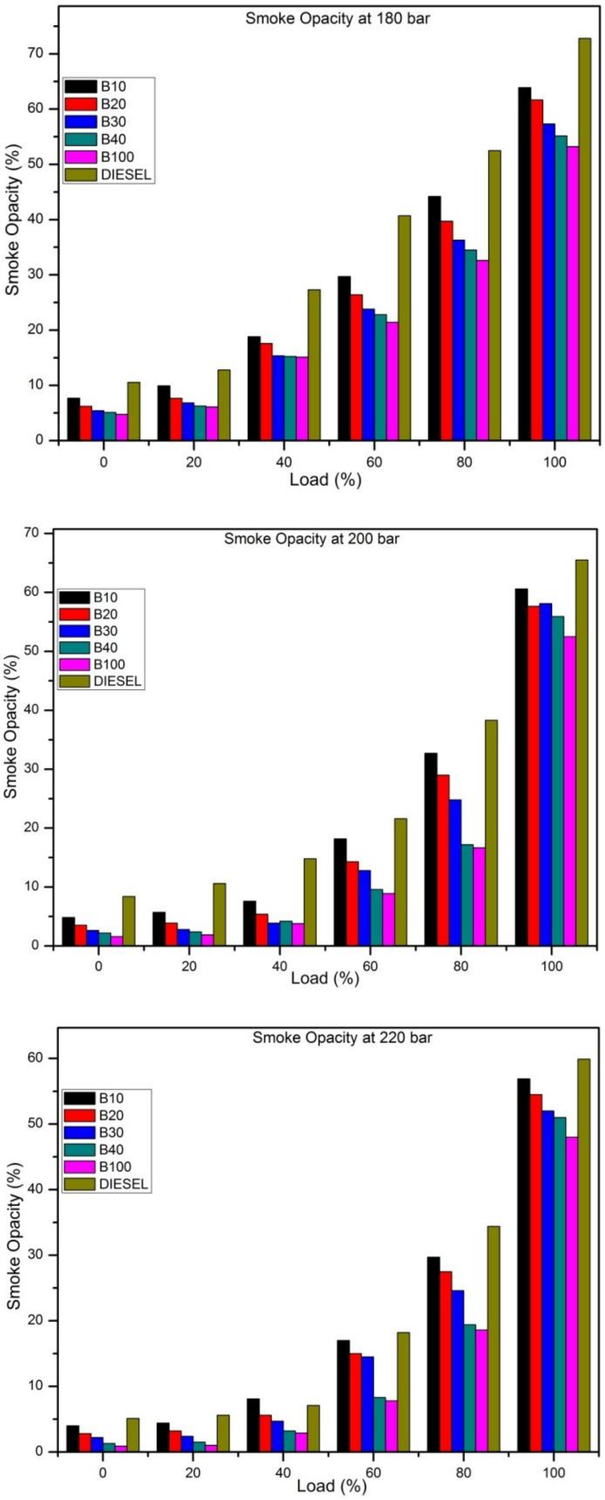


Fig. 12 Variation of Smoke Opacity with increasing load for different blend samples at different Injection pressure (180 bar, 200 bar and 220 bar).

4. Conclusion

The overall study was done on the extraction of scum oil methyl ester from dairy wash water for production of bio-fuel, characterization of fuel, engine performance, combustion and exhaust emission characteristics of scum oil methyl ester and its blends with diesel. Various samples was prepared using diesel and scum oil methyl ester such as B10, B20, B30, B40, B100 and D100, The experiment was carried out on a computerized compression ignition four stroke, single cylinder, water cooled with high data acquisition system, eddy current dynamometer, piezoelectric transducer and five gas exhaust calorimeter diesel engine test rig. In the current study performance combustion and emission characteristic was done for three different injection pressures (180, 200 and 220 bar) for all the prepared fuel samples.

The following conclusions are drawn from the work carried out.

BSFC of diesel and biodiesel blends was compared, the results shows that BSFC of the diesel is less compare to biodiesel blends. Average BSFC for diesel was 0.347, 0.238 and 0.321 kg/kW.hr at 180, 200 and 220 bar respectively.

Variation of BTE was compared for both diesel and biodiesel blends at three operating pressure. The plotted graph shows that BTE is more for diesel than the SOME blends in case of all the three operating pressures. Since flash and fire point of SOME blends was high due to which there was an ignition delay take place inside the cylinder.

From the experimental data it was found that there was 20-50 per cent reduction in CO emission with increase in injection pressure from 180 bar to 200 bar. This is caused because of percentage of oxygen percent in bio-fuel is more than in conventional diesel and also with high pressure injection complete mixing of fuel particles takes place with air which leads to complete combustion. For B20 blend sample, CO emission was very much less than diesel and also with other blends for all the three operating pressure.

Diesel and SOME blends was compared with three operating pressures with respect to diesel, it was found that initially HC emission will be more for diesel than SOME blends. With increase in load and injection pressure there was a drastic increase in HC emission for diesel blends. Hence for the better performance of CI engine B20 sample can be used as an alternate fuel which satisfies all the properties of diesel.

It was found that there was raise in NOx emission by 22, 20 and 36 PPM from B20 to D100. The major problem when blends of biodiesel were used as fuel in CI engine, it will produce more amount of NOx emission than the diesel fuel. But the difference amount of NOx emission between B20 and D100 was very less; hence this amount of NOx emission will not affect much on environment and also on engine performance. Because of this B20 blend sample can be used as an alternate fuel for CI engine.

From combustion analysis, it was observed that shorter ignition delay and high Cylinder Pressure with less heat release rate obtained for B20 than other test fuels.

From the overall results obtained for all the blends of diesel with scum oil methyl ester and diesel at three operating injection pressure it can be concluded that B20 sample can be used as an alternate fuel at an injection pressure of 200 bar in to CI engine without any modification. These samples will give better performance and less exhaust emission than any other blends.

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