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Experimental Investigation and Assessment of Performance and Emission Chracteristics of CIME Fuelled CI Engine

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Abstract—the modern transport system runs primarily on fossil fuels and they are non-renewable cheapest sources of energy. Considering the huge demand of diesel in transportation sector, biodiesel can serve as an innovative alternative to power the vehicles. In the present study, Biodiesel from Calophyllum Inophyllum non-palatable oil has been extracted from Transesterification process by considering effective Free Fatty Acid as per ASTM D 6751 standards and the properties of Calophyllum Inophyllum Methyl Ester was evaluated with those of pure diesel and the same fuel has been used in the conventional engine without any alterations in the operating conditions. Experimental campaigning is done to analyse the performance characteristics of diesel fuel and different proportions of Biodiesel mix (20%, 40%, 60%, 80% and 100%). The performance attributes such as Indicated power, Indicated Thermal Efficiency, Brake Thermal Efficiency, Volumetric Efficiency, Mechanical Efficiency, Brake Specific fuel consumption have been calculated from results arrived based on experimentation. Emission attributes and Exhaust Gas Temperature were measured for all tested fuels. The results obtained for all mixed blends were compared with the neat diesel performance and emission results. The results unveiled that CI 20 (20% Biodiesel and 80 % Diesel) yields enhanced performance and significantly less emisions when compared to other proportions.

Key Words—Calophyllum Inophyllum Methyl Ester; Diesel; Engine, Transesterification; Blends; Free Fatty Acid.

1 Introduction

The increasing demand of fossil fuels, with the increase in their prices and production of harmful environmental pollution has made it very important to find alternative resources of fuel. Biodiesel is one such alternate form of energy that can help resolve this issue and also is renewable, non-toxic and less polluting either palatable or Non-Palatable Bio Oil [1-4].Fossil fuels are now considered to be one of the most basic and important needs for all. Many industries like Agriculture, Transportation, Manufacturing Industries, Thermal Plants etc., run majorly on fossil fuels. Electricity Generation is also majorly done by fossil fuels, which has an effect on the global economy. Owing to rise in fuel consumption, the economy of the country witnesses the increase in import of the fuel varying from 4.187×10^{15} to 10.457×10^{15} BTU [5, 6].

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Biodiesel refers to a vegetable oil-based diesel fuel with an alkyl Ester. This basically can be produced by a combination of chemicals and any natural oil with an alcohol producing esters. The natural oil in this case can be an edible or a non-edible oil, which later processed, will be ready for a reaction to produce Biodiesel. Production of biodiesel can be done with different methods namely supercritical process, Ultrasonic Reactor Method, Lipase Catalyzed Method etc. Biodiesel possesses properties which makes it easier for it to blend with diesel. So, basically, this is referred to with a suffix 'CI'. CI100 Stands for 100% Biodiesel, CI20 stands for 20% Biodiesel and 80% Petro diesel. Blending of these biodiesels can be achieved in different ways such as Splash Mixing, In-line mixing, Metered Pump Mixing etc., [7,8].

Arumugam et al [9] studied the tribological and combustion performance of CI engine charged with neat diesel and diesel-blended with castor oil. The study substantiated that blending of diesel with castor resulted in enhanced lubrication thereby causing a reduction in wear and improvement of engine life.

Anbarasu et al [10] studied the functional performance and emission output of diesel engine using canola biodiesel-water emulsified fuel. The emulsified fuel were assessed for its viscous nature, density, fluidity behaviour (pour point) and the engine performance parameters were evaluated. The results disclosed that emulsification through water has the capacity to further the engine working conditions and subsequently reduce the pollutants.

Vijayakumar et al [11] demonstrated the technique of transesterification in extracting biodiesel from crude Mahua oil containing free fatty acid of the order of 21% resulting in production of 85% Mahua methyl ester (MME). The study unveiled that FFA level drops down significantly and on the other hand higher yield of MME favours the durability of the engine in terms of emission and combustion characteristics.

Prabu et al [12] instilled oxygenated mixture containing ethylene and propylene glycol in jatropha biodiesel and assessed the CI engine for its level of emission and performance. The results showcased that slighter rise in brake thermal efficiency and retardation of smoke and HC of the order of 27% and 11% respectively.

The studies reveled that, the performance characteristics of CI Engine have been assessed for different biodiesel mix and the results favored acceptable thermal efficiencies with considerable rise in fuel consumption rate and temperature of exhaust gas. And also, it has been observed from earlier investigations of biodiesel extraction process for Calophyllum Inophyllum that the number of acid esterification process and degumming process used was numerous to reduce the Free Fatty Acid (FFA) which reduces the fuel quality and imposed a constraint in the performance.

The work pertaining to reduction of total cost of biodiesel production with minimal number of iterations performed on acid esterification for the reduction of FFA parameter and complete elimination of degumming process is very much limited. Hence the study is focused on reduction of FFA factor, mixing different proportions of blend with diesel and computing its performance and emission attributes.

2 MATERIALS AND METHODS

2.1 Biodiesel Production Process

Biodiesel is basically a methyl ester. It can be obtained by Transesterification of any bio oil, vegetable oil or animal fat. In this work Calophyllum Inophyllum oil was used which is a Non-Palatable oil. The calophyllum inophyllum seeds were first segregated and crushed to obtain oil. They have a huge oil content of over 60-65% weight of the seed. The oil is then filtered to remove any unwanted impurity. The methyl ester is obtained by the catalytic reaction of the obtained Non-Palatable crude oil with methanol or ethanol under Sodium hydroxide or potassium hydroxide solution [13, 14].

2.1.1 FFA Testing

FFA testing is done by dissolving 1ml of the obtained crude oil with 10ml isopropyl alcohol in a conical flask. 2-3 drops add Phenolphthalein indicator is added to know the change in colour. And then a 1N solution of NaOH is made. The solution in the conical flask is titrated against the 1N NaOH solution and stirred gently till a pale pink colour is obtained and this is shown in Figure 1. By knowing the amount of solution used for titration, FFA was tested.

During the first stage of extraction, the bio oil is first esterified to reduce the FFA content. In a round bottom flask one litre of the crude oil is poured gently and heated to about 55°C while gently being stirred using a magnetic stirrer. Meanwhile 150ml of Methanol is added with 2.5ml of H_2SO_4 in a separate flask. Once the temperature of the crude oil reaches 55°C the mixture prepared in the flask is poured gently to the round bottom flask. It is then heated for around 1hr at a constant temperature of 55°C. The crude oil is then allowed to settle so that the water gets collected at the top which is removed to obtain the Tri-glyceride. The obtained oil is again tested for FFA and if the FFA is found to be above 2.5, it is again subjected to the same process till the FFA reached below 2.5[15].

FFA test is done for acid esterified fuel and it measured was 1.95% and this FFA value achieved without degumming process and it is compared with the previous value which was obtained from acid esterification done with many trails and a reduction of 20%-30% of the process was observed.

Figure 1 FFA testing

2.1.2 Transesterification

Once the FFA content reached below 2.5, transesterification process is done where the final Biodiesel is obtained. One litre of the obtained crude oil from previous stage is heated for till it reaches 55°C in a round bottom flask. Meanwhile 200ml of Methanol is added with 6.5g of 1N NaOH solution separately in a flask. Once the crude oil reaches a temperature of 55°C the mixture prepared is gently added to the crude oil and heated at a constant temperature of 55°C and stirred continuously with the help of a magnetic stirrer. The chemical reaction and process set up are exposed in Figure 2 and 3.The oil is the allowed to settle for some time so that the biodiesel floats at the top while the glycerine settles at bottom and it is depicted in Figure 4. The glycerine is separated and the biodiesel is obtained.

2.1.3 Water washing and heat treatment

The obtained biodiesel has a lot of impurities like alcohol and soap content. This can be removed by water washing method. Once water washing is done the biodiesel will still have some water content in it, hence Heat treatment is given and method is depicted in Figure 5.

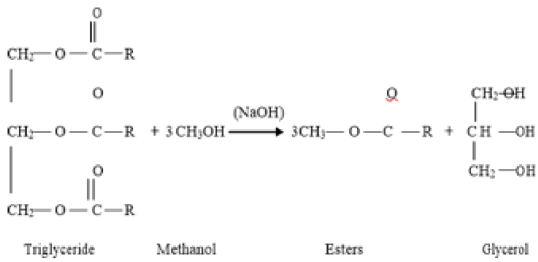

Figure 2 Transesterification –Chemical reaction

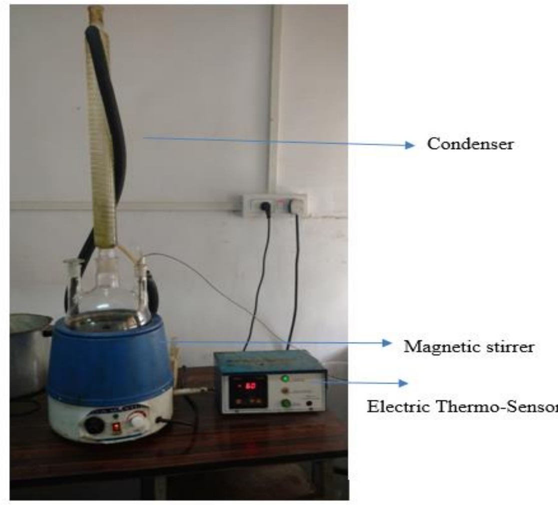

Figure 3 Transesterification process setup

Figure 4 Settling and separation

Figure 5 Heating & water washing

Here the biodiesel is heated at a constant temperature of 110-120^{o}C till all the water content is removed and the process is depicted in Figure 6. Finally the obtained product is pure biodiesel free from fatty acids and impurities. The Glycerol is separated from the mixture once it settles down and the ester is water treated and then heated to remove any unwanted moisture and impurities.

Once the biodiesel extracted from the above process, the corresponding properties have been tested and measured as per ASTM standards and listed in Table 1 and 2.

Figure 6 Final bio diesel

2.1.4 Preparation of Blend

The obtained oil is blended in different ratios of biodiesel (CI20-100) to carryout performance test, this is shown in Figure 7.

2.2 Experimental Setup and Experimental Test on Prepared CIME

The naturally aspirated direct injection four stroke water cooled single cylinder engine of rated power 5.2 kW and speed 1500 rpm was chosen for the study. The engine experimental set-up and its process attributes are shown in Table 3 and 4. The combustion was direct injection type. The line diagram and Photographic view of experimental set up is illustrated in Figure 8 and 9. Initially the engine was run with diesel fuel and on reaching the operating temperature, the engine performance and Emissions were assessed for different load levels. Knowing the emissions, consumption of fuel and rate of mass flow was calculated. The same setup was used for testing of Biodiesel for different test ratios of pure biodiesel in the order of CI20, 40, 60, 80 and 100. CI100 means pure biodiesel [16, 17]. The flow diagram of experimental work is represented in Figure 10.

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TABLE 1
PROPERTY COMPARISON OF BIODIESEL BLENDS WITH NEAT DIESEL

Description	Flash point (^{o}C)	Fire point (^{o}C)	Kinetic viscosity @ 40^{O}C (m^2/s) $\times 10^{-4}$	Gross calorific value (kJ/kg)	Net calorific value (kJ/kg)	Specific gravity @15^{O}C	Free fatty acid (%)	Cetane Number
CI Crude Oil	218	238	1.27	37050.99	34323.86	0.95	25.3	-
Neat Diesel	52	58	0.06	44000	42500	0.83	-	47
CI20	73.6	78.8	0.0648	42901.07	41173.88	0.845	-	-
CI40	95.2	99.6	0.0696	41802.14	39847.77	0.860	-	-
CI60	116.8	120.4	0.0744	40703.2	38521.65	0.875	-	-
CI80	139.6	141.2	0.0792	39604.28	37195.54	0.890	-	-
CI100	160	162	0.084	38505.352	35869.43	0.906	1.95	56

TABLE 2
DETAILED CHEMICAL PROPERTIES OF CRUDE OIL AND CIME

Parameter	Method	Unit	Result: Crude Oil	Result: CIME
Flash Point	IS:1448 (Part 66) -1969	^{o}C	218	160
Fire Point	IS:1448 (Part 66) -1969	^{o}C	238	162
Kinematic Viscosity @ 40^{o}C	IS :1448(Part 25)-1976 Reaff 2013	**m^2/s**	1.27×10^{-4}	0.084×10^{-4}
Gross Calorific Value	IS:1448 (Part-6) 1984 Reff 2013	kJ/kg	37050.99	38505.35
Net Calorific Value	IS:1448 (Part-6) 1984 Reff 2013	kJ/kg	34415.07	35869.43
Density	IS:1448 (Part 32) -1992 Reaff 2013	Kg/m^3	950	905
Ash Content	IS: 1448 (Part 4) -1984 Reaff 2013	%	0.037	0.019
Sulphur as S	IS: 1448 (Part 33)-1991 Reaff 2013	%	0.002	0.23
Cloud Point	IS:1448 (Part 10) -1970 Reff 2013	^{o}C	15	18
Pour Point	IS:1448 (Part 10) -1970 Reff 2013	^{o}C	10	06
Specific gravity @ 25^{o}C	IS:1448 (Part 32)-1992 Reaff 2013	-	0.95	0.906
Total Acid Number	IS:1448 (Part 86) -1997 Reaff 2016	Mg KOH/g	33	1.9
Carbon Residue Ramsbottom	IS:1448 (Part 10)- 1970 Reaff 2013	%	1.3	0.58
Free Fatty Acid	Clause 7 of IS: 548 (Part 1)-1964	%	25.3	1.95

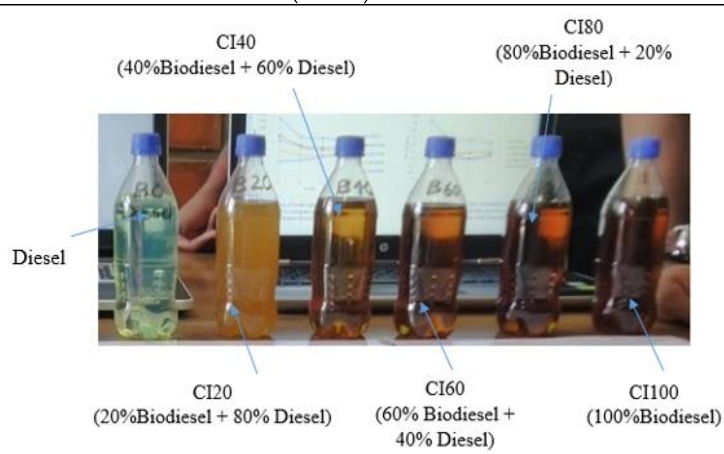


Figure 7 Bio diesel blends

TABLE 3

ENGINE SPECIFICATIONS

Parameters	Dimensions
Type	Four stroke, single cylinder vertical water-cooled Diesel Engine
Rated power	5.2 kw
Rated speed	1500 rpm
Bore diameter (D)	87.5 mm
Stroke length (L)	110 mm
Compression Ratio	17.5: 1
Fuel Properties	
C.V of Diesel	42,500 kJ/kg
Density of Diesel	830 Kg/m^3
C.V of Bio Diesel	35869.43KJ/Kg
Density of Bio Diesel	905 Kg/m^3

TABLE 4
EDDY CURRENT DYNAMOMETER SPECIFICATION

Parameters	Dimensions
Make	Techno Mech
Model	TMEC-10
kW	Nm*RPM/9549305
Max kW	7.5
Dynamometer arm length	185 mm
RPM	1500-6000

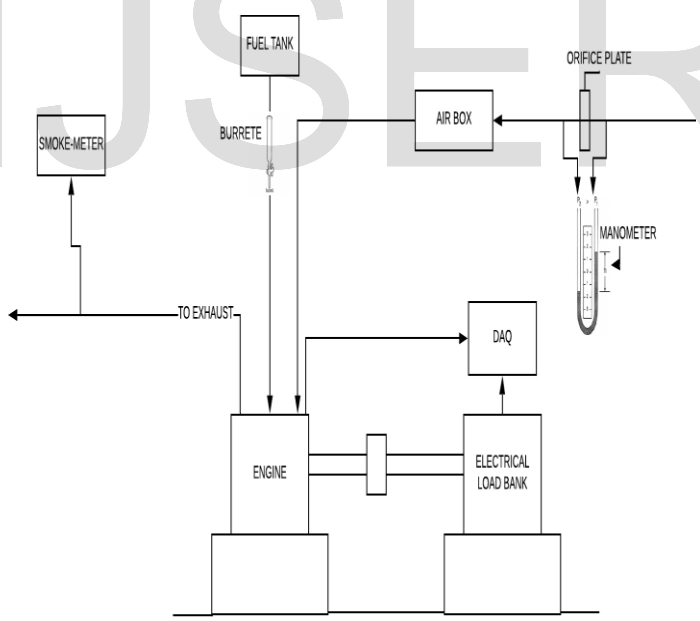
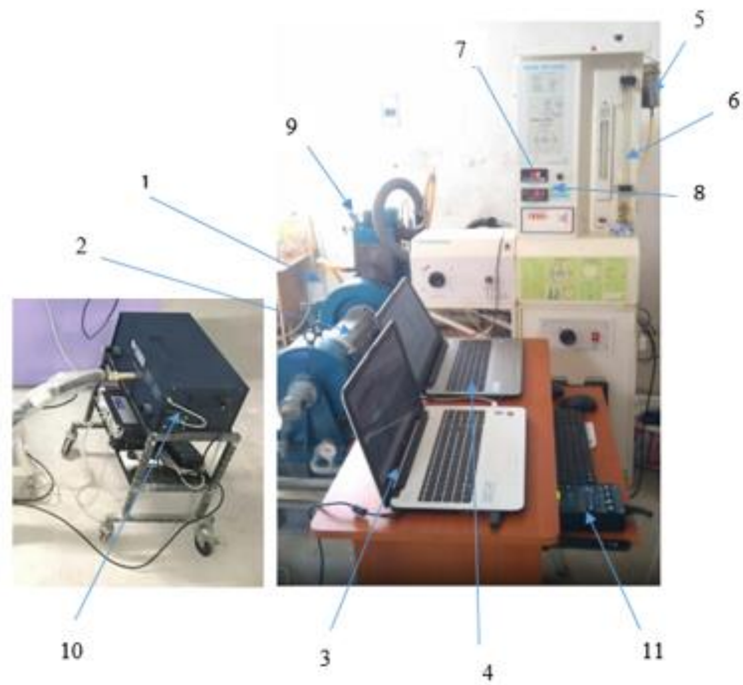


Figure 8 Line diagram of test rig



1. Kirloskar Model TV1 single Cylinder Diesel Engine
2. Eddy Current Dynamometer
3. DAQ for Emissions
4. DAQ for Performance and Combustion Characteristics
5. Fuel Tank
6. Burette
7. Electric Load Digital Indicator
8. Mechanical Load Digital Indicator
9. Fuel Injector
10. AVL 5Gas Analyser
11. Smoke Meter

Figure 9 Photographic view of engine test rig

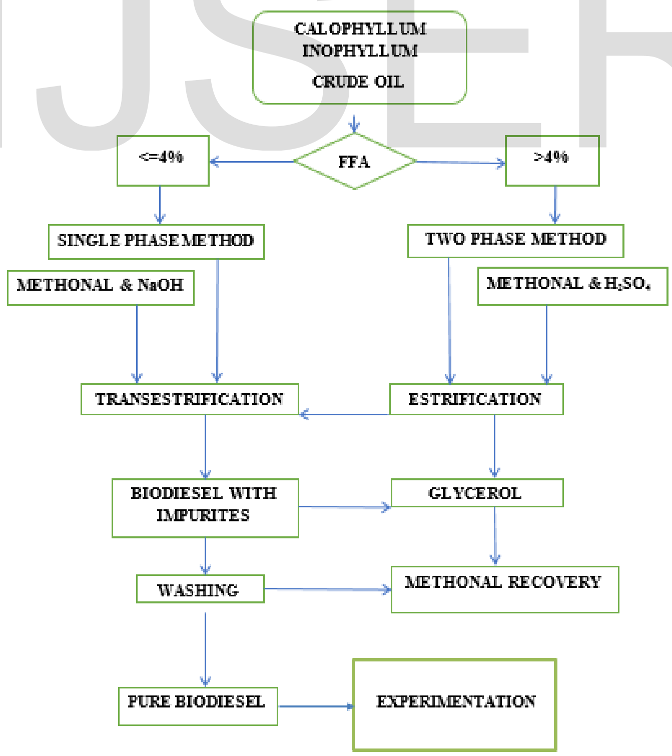


Figure 10 Flow diagram of experimental work

3. Results and Discussion

3.1. Brake thermal efficiency (BTE)

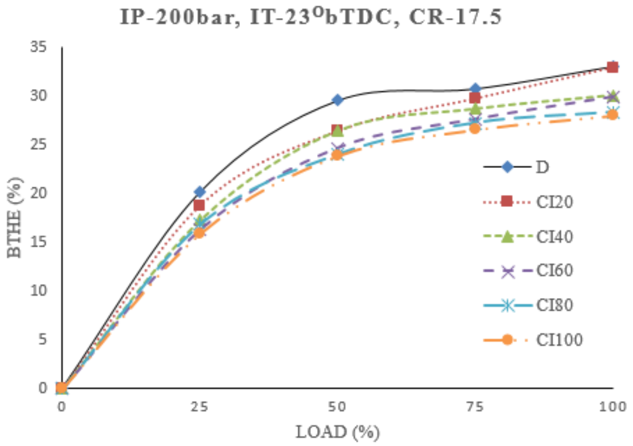


Figure 11 Influence of Load on brake thermal efficiency under various biodiesel-diesel blends

The observation of BTE with increment in the load is shown in Figure 11. It is inferred that, at full load of neat diesel and blending conditions from CI20 to CI100, the observed brake thermal efficiency are 33.04%, 32.9%, 31.32%, 30.76%, 29.03%, 28.9% respectively. The noticeable deviations between the blended and un-blended are 0.42%, 5.2%, 6.9%, 12.14% and 12.5%. It is observed that there is a declining trend in the engine performance converting the heat available in the fuel to mechanical energy i.e. brake efficiency, which is attributable to lower heat generation resulting from the incomplete combustion of fuel. Also, the associated atomization and subsequent vaporization effecting from high viscous nature of blends culminates in erratic combustion nature [18].

3.2. Indicated thermal efficiency (ITE)

The effect of load on ITE is revealed in Figure 12 and it contingent that The maximum Indicated thermal efficiency at full load with neat diesel and different blends from CI20 to CI100 are 45.78%, 43.59%, 41.61%, 40.98%, 40.1% and 39.38% respectively and standard deviation for various proportions of composite fuels are 4.7%, 9.1%, 10.48%, 12.4% and 13.9%. A decreasing phenomena is observed in the indicated thermal efficiency which may be due to subsequent rise in proportion of biodiesel in the biodiesel-diesel blend. Also, decrement in calorific value with the percentage increase in biodiesel and fuel consumption rate adds to the factor. There is an anomaly between CI20 and CI40 due to decrease in atomization [19]. It can be seen that CI20 provides a stable indicated thermal efficiency with respect to loads and shows more similarities to the neat diesel.

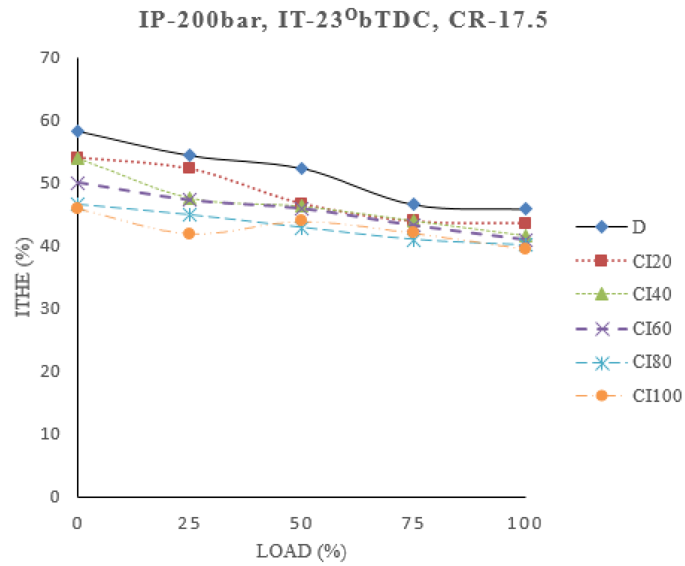


Figure 12 Influence of Load on indicated thermal efficiency under various biodiesel-diesel blends

3.3. Mechanical efficiency (ME)

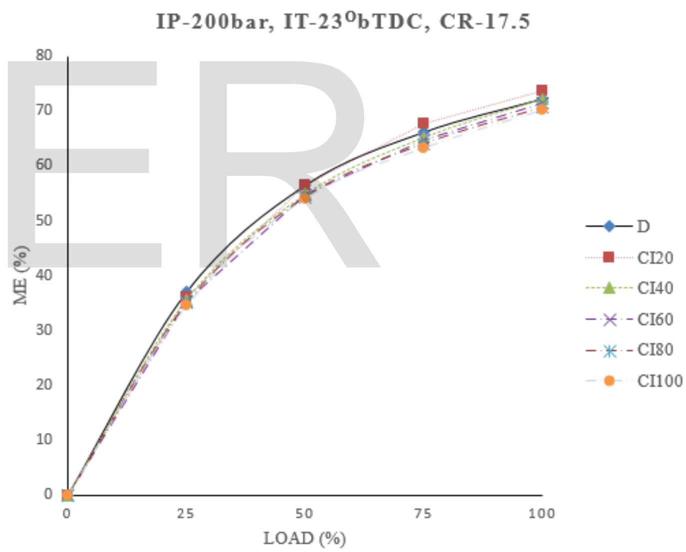


Figure 13 Influence of Load on mechanical efficiency under various biodiesel-diesel blends

The influence of load on ME is indicated in Figure 13 and it is revealed that, at full load with neat diesel and different blends from CI20 to CI100, the maximum efficiency are attained 72.18%, 72.01%, 71.42%, 71.2%, 70.6%, 70.3% respectively. The standard deviation for various proportions of biodiesel mix noted as 0.23%, 1.05%, 1.35%, 2.2% and 2.6%. The decrease in efficiency of various blends are due to variation in the atomization and vaporization of the blend mixtures and this is attributable to the frictional rise between the moving parts contributing to enhanced mechanical efficiency. Also the high viscous nature in mix of biodiesel leads the improper combustion [19]. It can be seen that CI20 has more mechanical efficiency as compared to other blends.

3.4. Indicated power (IP)

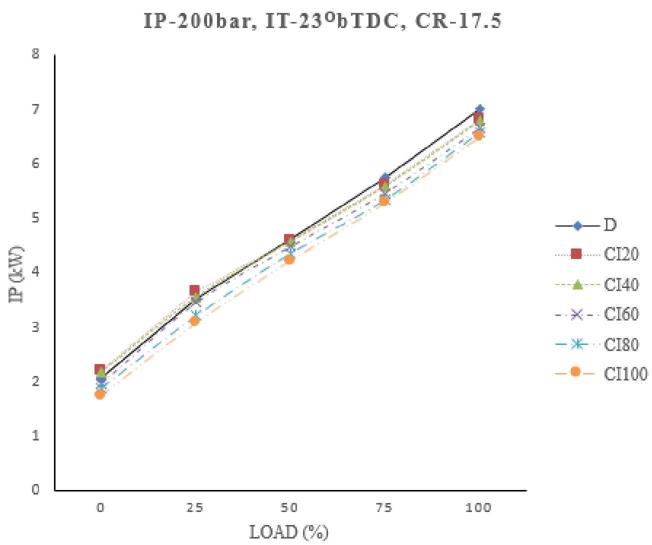


Figure 14 Influence of Load on indicated power under various Biodiesel-diesel blends

The observation of IP with increment in the load is shown in Figure 14. The inference revealed that the maximum Indicated power at full load with neat diesel and different blends from CI20 to CI100 are 7, 6.83, 6.76, 6.74, 6.7, 6.64 kW respectively and the deviation are 2.42%, 3.43%, 3.7%, 4.28% and 4.57%. It is inferred that IP showed a decreasing trend with rise in the combinational of blend (Biodiesel-Diesel mix). IP rises with rising load, with the acceleration of the throttling operation in order to run the engine under the same speed for varying load, which could be due to increase in mean effective pressure [20].

3.5. Volumetric efficiency

The observation of volumetric efficiency with increment in the load is depicted in Figure 15. It is inferred that The Volumetric efficiency at full load with neat diesel and different blends from CI20 to CI100 observed was 84.33%, 82.17%, 81.9%, 81.56%, 80.8%, and 80.4% respectively. The standard deviation for various proportions of biodiesel mix noted as 2.56%, 2.88%, 3.28%, 4.18% and 4.66%. Volumetric efficiency decreases due to increase in load as more air-fuel mixture is required during higher load and less utilization of oxygen for the said ratio of Air-Fuel mixture. The blended mix shows low volumetric efficiency due to low atomization property [20]. This is attributable to the complete utilization of air fuel mixture during higher loads [18].

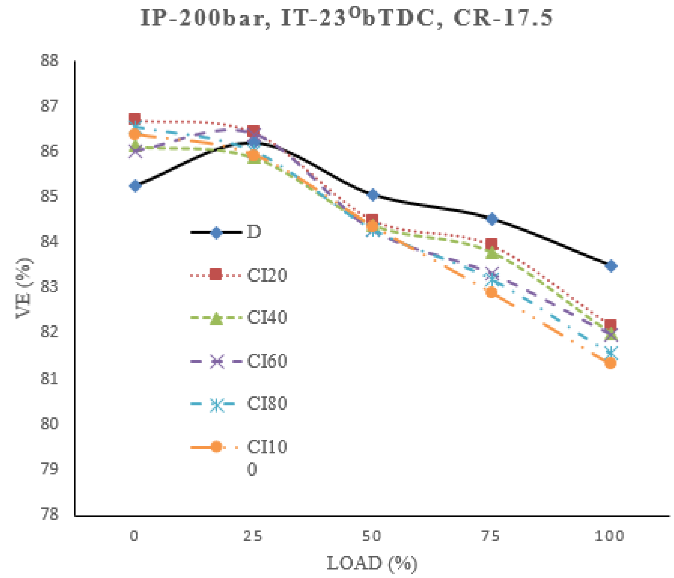


Figure 15 Influence of Load on volumetric efficiency under various bio-diesel-diesel blends

3.6. Brake specific fuel consumption (BSFC)

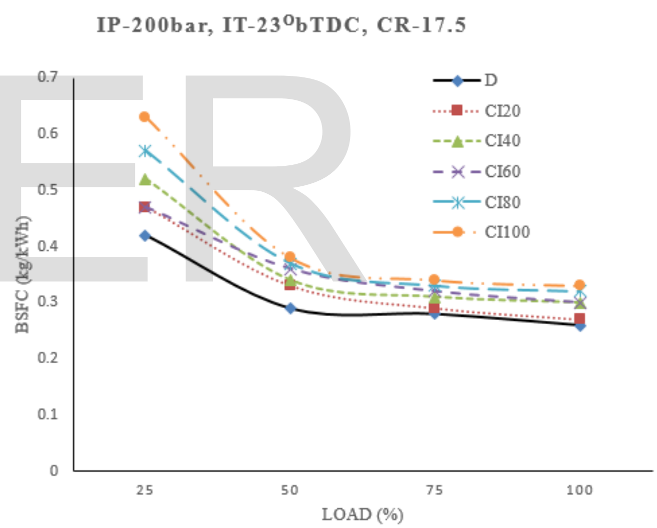


Figure 16 Influence of Load on specific fuel consumption under various biodiesel-diesel blends

The observation of BSFC with increment in the load is illustrated in Figure 16. It is inferred that Brake specific fuel consumption is the ratio of total fuel consumption for 10mL fuel to the Brake power. When BP is 0 i.e. load is the BSFC tends to infinity and hence cannot be compared with other loads during analysis. The BSFC at full load with neat diesel and different blends from CI20 to CI100 are 0.26, 0.27, 0.29, 0.3, 0.33, 0.34kg/kW.hr for blends CI0, CI20, CI40, CI60, CI80, CI100 respectively and also it is seen that from standard deviation for various proportions of composite fuels are 3.84%, 11.53%, 15.38%, 26.92%, 30.76%. It can be seen that BSFC increases with increase in biodiesel percentage in the blend, which means the fuel efficiency decrease with increase in biodiesel percentage in the blend as observed in the standard deviation

[19]. It can be observed that BSFC decrease with increase in load, because, there is an improvement in total fuel consumption for a higher increase in load or BP.

3.7. Exhaust gas temperature (EGT)

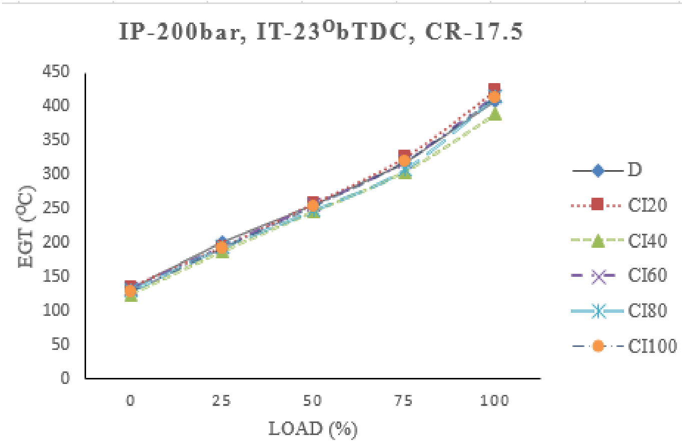


Figure 17 Influence of Load on exhaust gas temperature under various biodiesel-diesel blends

The observation of EGT with increment in the load is portrayed in Figure 17. It is inferred that Exhaust gas temperature is the temperature measured at the outlet of the engine. Exhaust gas temperature varies with the type of engine, fuel, ignition quality, compression ratio and outlet parameters. The gas temperature at the exhaust under full load with neat diesel and different blends from CI20 to CI100 are 409.46K, 414.3K, 418.23K, 422.2K, 425.8K, and 428.6K respectively. The standard deviation for various proportions of biodiesel mix noted as 1.2%, 2.14%, 3.11%, 3.99% and 4.67% for all proportions of blend. It can be seen as load increases EGT and its deviation increases due to oxygen availability in biodiesel mix at higher loads which improves the combustion process yielding higher EGT [19].

3.8. Carbon monoxide (CO) emission

The influence of load on CO emission is depicted in Figure 18. The results inferred for CO emission of diesel and different proportions of biodiesel blends such as CI20, CI40, CI60, CI80 and CI100 are 0.257%, 0.241%, 0.237%, 0.218%, 0.189% and 0.157% at full load respectively. It has been observed when blend increases CO emission significantly decreased by 6.22%, 7.78%, 15.17%, 26.45% and 38.9% than compare to diesel. This was mainly due to high oxygen content in biodiesel than compare to diesel which leads the complete combustion of charge, thus reduce the CO emission [18-20].

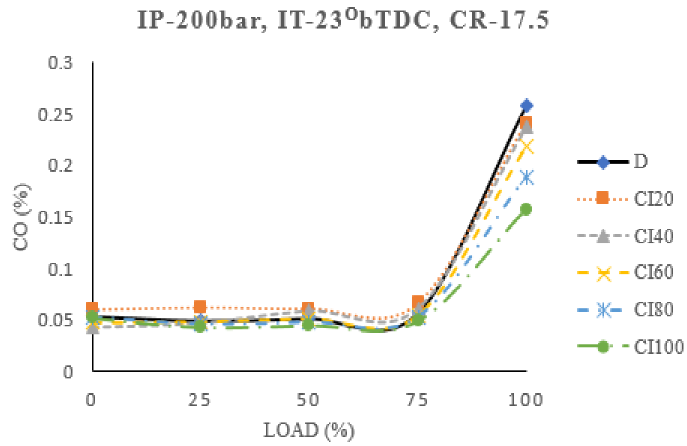


Figure 18 Influence of Load on CO emission under various biodiesel-diesel blends

3.9. Hydro-Carbons (HC)

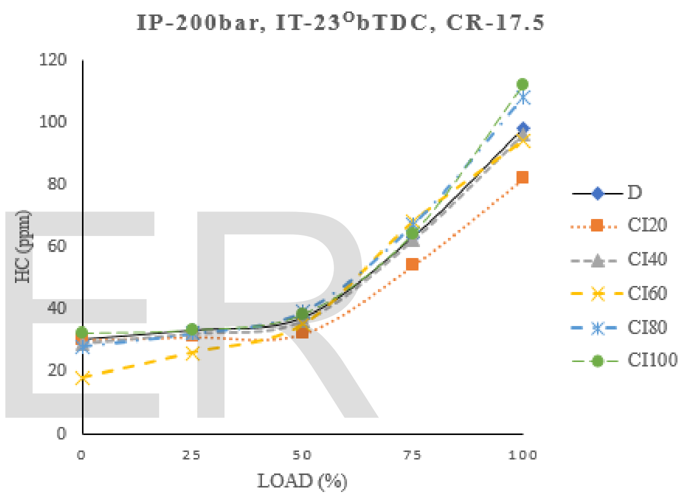


Figure 19 Influence of Load on HC emission under various biodiesel-diesel blends

The observation of HC emission with increment load is portrayed in Figure 19. For diesel and different proportions of biodiesel blends such as CI20, CI40, CI60, CI80 and CI100 HC emission were noted as 98, 82, 96, 94, 108 and 112ppm at full load respectively. It has been observed for CI20, 40 and 60 HC emission decreased by 16.3%, 2.04%, 4.08% this was due to high oxygen content in the blends that resulting in complete combustion. But HC emission increased by 10.2% and 14.28% for CI80 and 100 than diesel this was mainly due to high viscosity in 80 and 100% biodiesel[18-20].

3.10. Carbon dioxide emission (CO_2)

The effect of load on **CO_2** emission is illustrated in Figure 20. For diesel and different proportions of biodiesel blends such as CI20, CI40, CI60, CI80 and CI100.

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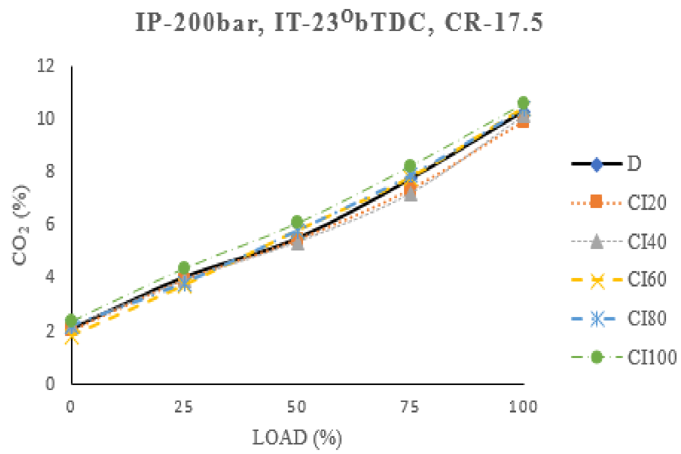

Figure 20 Influence of Load on CO_2 emission under various biodiesel-diesel blends

The results of all tested samples were as 10.3%, 9.89%, 10.12%, 10.43%, 10.38% and 10.6% at full load respectively and it was observed when blend increases CO_2 decreased by 3.9%, 1.7% and 1.2% for CI20, 40 and 60% blend, this was due to as load increases the mixture becomes rich which resulting in high oxygen content in the mixture, thus complete combustion of charge occurred. But it had increased for CI80 and 100% blend by 0.77% and 2.9% was mainly due to high viscous nature in higher proportions of blend [18-20].

Oxygen emission (O_2)

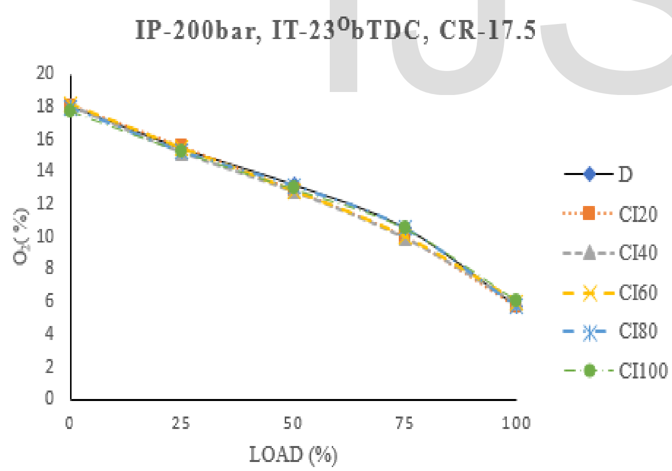

Figure 21 Influence of Load on O_2 emission under various biodiesel-diesel blends

The impact of load on O_2 emission is portrayed in Figure 21. For diesel and different proportions of biodiesel blends such as CI20, CI40, CI60, CI80 and CI100 and O_2 emission was exposed as 5.69,5.73, 5.94, 5.97, 6.01, 6.07% at full load respectively, it seen when blend increases O_2 increased by 0.7%, 4.3%, 4.9%, 5.6% and 6.6% than to diesel fuel. This was occurred due to high adiabatic flame temperature of biodiesel than diesel which resulting in higher O_2 emission at higher loads [18-20].

3.11. Nitrogen oxide (NO_x)

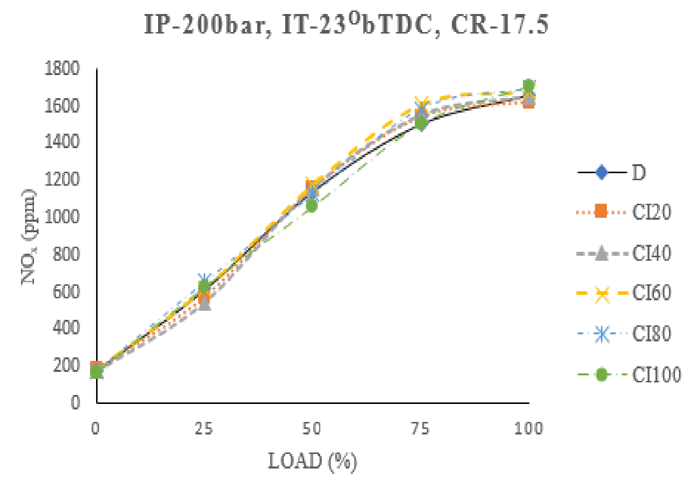

Figure 22 Influence of Load on NO_X emission under various biodiesel-diesel blends

The observation of NOx emission with increment is shown in Figure 22 for diesel and different proportions of biodiesel blends such as CI20, CI40, CI60, CI80 and CI100.The results reveals are 1655, 1623, 1650, 1682, 1694 and 1703ppm at full load respectively. It has been noticed when proportion increases the NO_x decreased by 1.9% and 0.3% for CI20 and CI40 blend, this was because of low adiabatic temperature and slight reduction in cylinder temperature at minimal blends but it has been observed that for CI60, 80 and 100% blend NO_x increased by 1.6%, 2.35% and 2.9% this was due to as proportion increases that increases the oxygen content in the mixture of fuel which causes the effective burning of fuel particles and increases the cylinder temperature. When the adiabatic flame temperature and cylinder temperature increases, NO_x increases [18-20].

3.12. Opacity

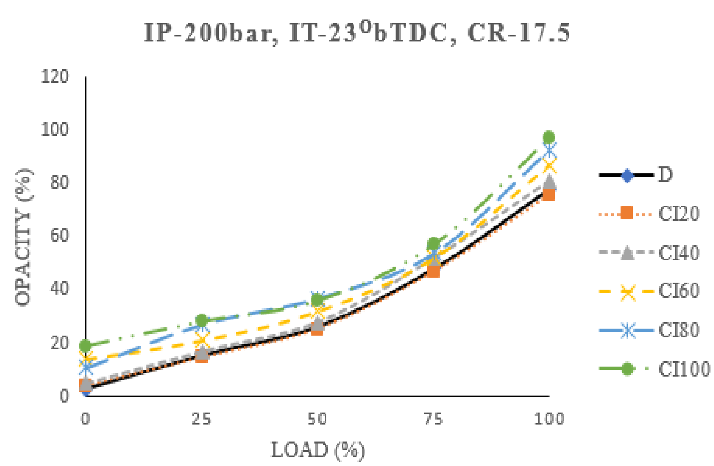

Figure 23 Influence of Load on Opacity emission under various biodiesel-diesel blends

The influence of load on opacity is illustrated in Figure 23 for diesel and different proportions of biodiesel blends such as CI20, CI40, CI60, CI80 and CI100 and the results shown are 78, 76, 81, 87, 92.7 and 97% at full load respectively. It inferred the opacity decreased by 2.56% for CI20 blend, but it has been observed that for CI40, 60, 80 and 100% blend opacity increased by 3.8%, 11.53%, 18.84% and 24.35% this was due to at lower proportions of blend had less carbon content and less fuel consumption rate than those of higher proportions of blends. As load increases resulting the smoke density increases mainly due to better combustion, higher specific fuel consumption which leaded to the rich mixture [18-20].

3 Conclusion

The performance and emission characteristics of unblended and blended (diesel-CIME) was examined and following conclusions were arrived at.

- Elimination of degumming and associated FFA process up to 20% to 30% significanyly, results in improvement of the process efficiency with possible reduction in cost, time and the all fuel properties met the ISO and ASTM standards.
- The characteristics of CI-20 are in good agreement with neat diesel.
- BTE was found for CI20 0.42% considerable reduction than diesel fuel which could be acceptable and this was decreased significantly for other blends such as CI40, 60, 80 and 100 which leaded to the lower BTE.
- ITE was decreased by 4.7%, ME was about 0.23% and VE had 2.56% for CI20 lesser than diesel which might be not affected to existing engine operation but this trend was increased for other proportion of fuel which could not be acceptable for the future experimental work.
- BSFC increases for higher proportions, therefore for CI20 it was about slight higher BSFC than diesel fuel.
- CI-20 manifest higher mechanical efficiency in contrast to other mix.
- CO emission for all tested blend was decreases and HC was found decreases significantly about 16.3% for CI20 than for other tested fuels.
- CO_2 was reduced about 3.9% for CI20 fuel with those of other tested fuels and diesel.
- NO_X was observed about 1.9% lesser than neat and other tested fuels.
- Opacity decreased 2.56% for CI20 fuel than compare to other tested fuel and diesel.

The study reveals that CI-20 blend mix proves favourable for the automobile applications in commercial aspect in terms of improvisation of fuel quality and performance, emission characteristics.

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