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Original Article

Variable Compression Ratio Diesel Engine Analysis by Ester of Karanja Oil Produced Using Heterogeneous Catalyst

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Abstract - *The ester of karanja oil was prepared using a solid catalyst. Calcium oxide (CaO) was prepared by calcium carbonate ($CaCO_3$). CaO was used to create lithium-impregnated calcium oxide or Li-CaO. KO was converted to biodiesel by the catalyst Li-CaO. The yield attained, at 60 °C and a 12:1 molar ratio of methanol to oil in 3 hours, was 95% by 4 % weight of Li-CaO. By combining 10, 20, 30, 50%, and 100% of KOME with diesel with a Compression Ratio (CR) of 17.5 and 15.4, an analysis of the diesel engine was conducted. At more CR, the engine performs better. Smoke and CO emissions decreased as CR increased. At 100% load, the blended fuel with the greatest BTE was 30.31% for BD10.*

Keywords - *Biodiesel, Karanja oil, Li-CaO, Karanja Oil Methyl Ester.*

1. Introduction

The CI engine is more efficient than the SI engine, but the CI engine emits more smoke, which creates more air pollution [1]. The CI engine fuel (diesel) is non-renewable, so its stock is limited, and it has become necessary to have renewable resources for the diesel engine. The researchers are finding diesel options for the CI Engine. Non-edible or edible oils are useful to make biodiesel and become a potential feedstock for CI engines. Edible oils have less FFA than non-edible oils, so producing biodiesel from them is simpler. Edible oils are not a sustainable resource for making BD, though, because they are utilized as food. For a country like India, edible oil is very costly, so BD from non-edible oils is advisable for diesel engines. Non-edible oils (neem, mahua, jatropha and karanja) are the ideal feedstock to produce the BD [2]. Karanja stands out among them as a desirable feedstock for biodiesel production. Karanja is a tree of modest size. There is sufficient oil (25-39%) in its seeds. KO contains a poisonous ingredient that prevents it from being used as nourishment for humans.

Thus, the oil is non-edible. The Free fatty acid content of KO is often greater than 2, so their transesterification is not advisable in a single step using a liquid catalyst (KOH and NaOH). By using a two-step procedure that involved a base catalyst (KOH and NaOH) for transesterification and a homogenous acid catalyst (H_2SO_4) for esterification, researchers were able to synthesize BD from KO [3-5]. Ester of KO was produced by Chauhan et al. [6] using a two-step procedure and used in the CI engine. The emission gas of Karanja bio diesel contains less smoke, CO and HC [7]. High viscosity and density create problems in conventional diesel engines if KO is used directly in the engine. So, it is not advisable [8].

Transesterification is a widely recommended process to modify the properties the vegetable oil. The properties (fire point, density, viscosity, flash point, etc) can be improved by this process. Various catalysts (liquid and solid) are used to rapid the process. The process can be completed either in a single step (direct transesterification) or two steps (first esterification and then transesterification), depending upon the FFA content of the oil. The FFA content of KO is generally more than 2. Therefore, first, esterification (to reduce the FFA) and then transesterification process are required using liquid catalysts like NaOH and KOH (9, 10). But liquid catalysts (homogeneous) have some disadvantages like, it cannot be recycled and are difficult to remove from the final product (biodiesel). The lengthy and intricate neutralization and purification processes result in a rise in process costs [5]. Solid catalysts in powder form (heterogeneous catalysts) overcome these problems. They are easily removed from the biodiesel and recyclable [10, 11]. Also, less amount of water required for washing of biodiesel. BD from oils were prepared by various heterogeneous catalysts (oxides of Calcium, Zink, Aluminium, Magnesium, Silica, etc).

Researchers have used BD generated from KO using homogeneous catalysts in either a single-step or two-step procedure to analyze the emissions and performance of diesel engines [12, 13]. However, according to our research, very few or no researchers have examined BD made from KO employing heterogeneous catalysts in a single step and tested on diesel engines with variable compression ratios.

In this work, Li-CaO was used as a solid catalyst to prepare BD from KO in a single-step process. Performance and emissions investigation of the C I engine was done at 15.4 and 17.5 compression ratios at various loading conditions for various blends of ester of KO with diesel and 100% diesel.

2. Material and Methods

2.1. Materials

KO, methanol, lithium nitrate, and calcium carbonate were procured from the local market. Chemicals were AR grades, and the purity of methanol was 99.8%.

2.2. Catalyst Preparation

Calcium carbonate ($CaCO_3$) was heated in a muffle furnace at 750 °C for 5 hr to produce the CaO. A solution of 2 grams of Li_3N and 10 millilitres of water was combined with 10 grams of CaO and 40 millilitres of water. It was stirred for 120 min and heated at 110 °C for 1 day. The final product was LiCaO.

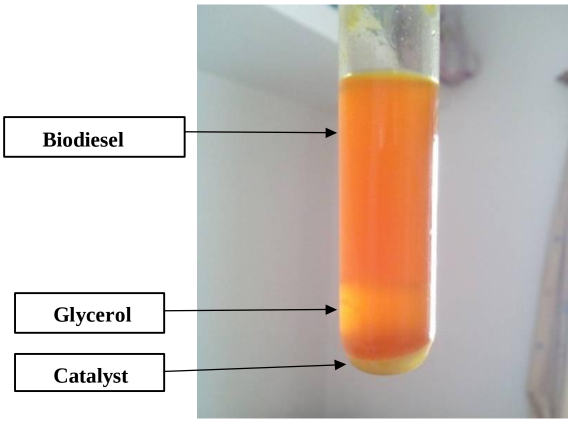
2.3. Preparation of KOME

In a single step, 200 mm of KO were transesterified using a 12:1 molar ratio of MeOH to oil and 5 weight percent of catalyst LiCaO. The mixture temperature was 60 °C, and the total time was 3 hr. The entire process was performed on a hot plate magnetic stirrer. The 95% yield was obtained using a heterogeneous catalyst. Figure 1 shows the catalyst and BD production. The properties of KOME and KO were tested, as shown in Table1.

Table 1. Properties of KO and KOME

Properties	KO	KOME
Density (g/cm^3)	0.92	0.87
FFA	2.6	0.23
Ester content	--	97
Calorific value (KJ/Kg)	34500	37200
Viscosity (mm^2/s)	40.90	4.6
Flashpoint (°C)	228	158
Moisture (mg/kg)	0.080	0.030

(a) Heating of $CaCo_3$ in furnace



(b) Biodiesel glycerol and catalyst separation
Fig. 1 Catalyst and biodiesel production

3. Experimental Setup

For the analysis of the BD made from KO, a computerized CI engine (4-stroke single-cylinder) with a variable compression ratio was employed. The experiment arrangement is shown in Figure 2. Torque was measured using an Eddy current dynamometer. The torque can be adjusted by the controlled system and displayed on the indicator. The K-type thermocouples were used to measure the various temperatures. The smoke meter (AVL 437C) monitored the amount of smoke. The Gas Analyser (TESTO 350) was utilized to analyze the emissions of NOx, CO_2, and other gases from exhaust gases. Initially, the engine ran at no load for 45 min. using D100. Engine tested at 0,25,50,75 and 100% load. Engine analysis was carried out for BD100 and BD20 at CR 17.5 and 15.4. Its results were compared with D100. A newly purchased computerized engine was used for getting precise readings. Detail engine specification is given in Table 2.

Fig. 2 Variable compression ratio diesel engine set-up

Table 2. Engine specification

Cylinders	1
Stroke length (cm)	11
Cylinder dia (cm)	8.75
CR	Can be vary from 10:1 to 18:1
Power output kW	4
Starting system	Battery operated
Fuel injection pump	Inline fuel pump
Speed (rpm)	1500
Capacity (cc)	660

4. Result and Discussions

4.1. Engine Performance Characteristics

The important engine parameters required to study are BTE, BSFC, emissions of CO, CO_2, NOx, and smoke. Figure 3 shows the comparison of BTE with load at CR 17.5 and 15.4 for blended fuel and D100. For every test, the efficiency rose as the load grew. Furthermore, in the majority of cases, the BTE at CR 17.5 is greater than the BTE at CR 15.4. Because of the improved air-fuel mixing and quicker evaporation that results in full combustion, the greater BTE at higher CR.

The greatest BTE for mixed fuels at CR was 17.5 CR for BD10 at 100% load, which was 30.31%. In the majority of situations, the BTE of BD100, BD50, BD30, and BD20 was less than D100 across the entire load range. Lower BTE is caused by KO and KOME's lower calorific values relative to D100. Additionally, the increased density and viscosity of KOME relative to D100 resulted in incorrect air-fuel mixing, which decreased BTE at higher blend percentages. The oxygen present in the BD may improve the combustion, so the BTE of BD10 is higher [6].

Raheman et al. [12] have obtained higher BTE for 20% and 40% blend of KOME (viscosity 9.6 mm^2 /s, calorific value 36,120 KJ/Kg) with diesel as compared to pure diesel. The BTE of B20 and B40 was 26.79% and 26.19% at full load, while at the same load, for diesel fuel, BTE was 24.62%, but he has not discussed any reasons for this higher efficiency. Lee et al. [13] have obtained lower BTE for a 40% blend of KOME with diesel at full load. He has obtained 37.5% BTE for BD40 and 39% for pure diesel at the same load condition. In addition, the BTE at all loads for BD40 was lower than diesel.

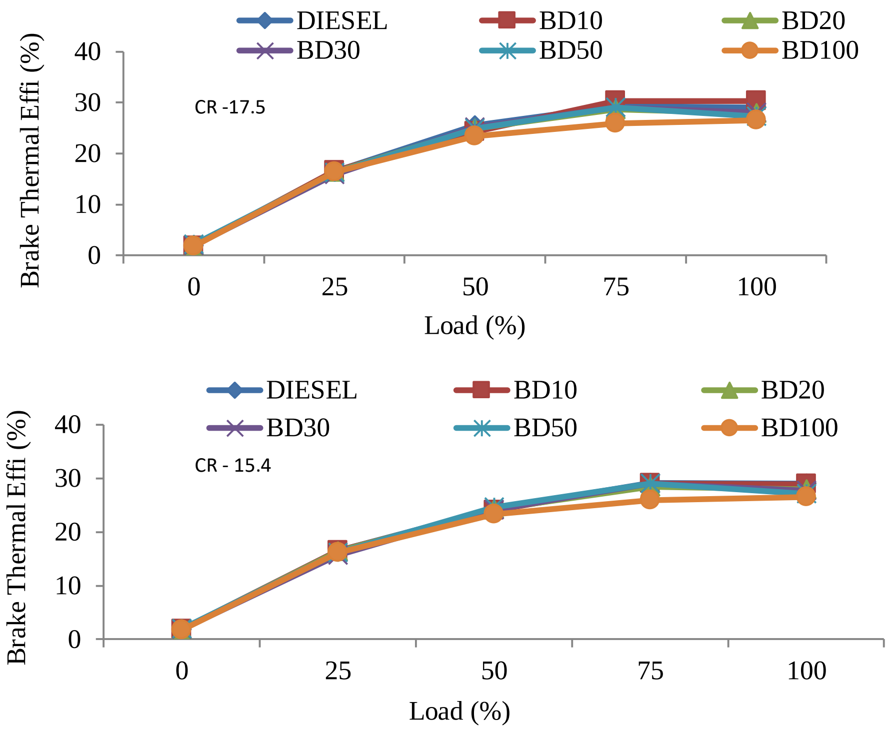


Fig. 3 Load versus BTE at CR 15.4 and 17.5

Figure 4 represents the effect of load on the BSFC for CR 17.5 and 15.4. It indicates that, for all mixes and neat diesel, the BSFC declined as the load increased. Additionally, for blended fuel, BSFC is higher than diesel fuel. This is caused by the higher density and lower CV of KOME compared to D100 [14]. However, at lower CR, an increase in BSFC is observed, which is due to the slow combustion process at lower CR.

Figure 5 represents the emissions of CO at various loads for the compression ratios 15.4 and 17.5. The graph shows that as the load climbed, so did the CO emissions. Higher loads cause the cylinder to fill with more fuel and the mixture to get richer, which increases the risk of incomplete combustion and CO emissions. However, the CO emissions for mixed fuels were lower than neat D100 for both compression ratios, which is due to the availability of oxygen in the molecules of KOME, which improves the combustion efficiency [15, 16]. The figure also indicates that, with the increase in CR, the emissions of CO are decreased at a particular load, which is due to high temperature at high CR leading to improved combustion efficiency, causing a reduction in CO.

Srivastava et al. [17] have obtained higher CO emissions (0.21%) for pure KOME at full load conditions as compared to diesel (0.18%) in a 10 HP single-cylinder diesel engine. However, compared to diesel fuels, the CO emissions from KOME's blended fuels (B5, B10, B15, and B20) were lower at 0.15%, 0.16%, 0.15%, and 0.18%.

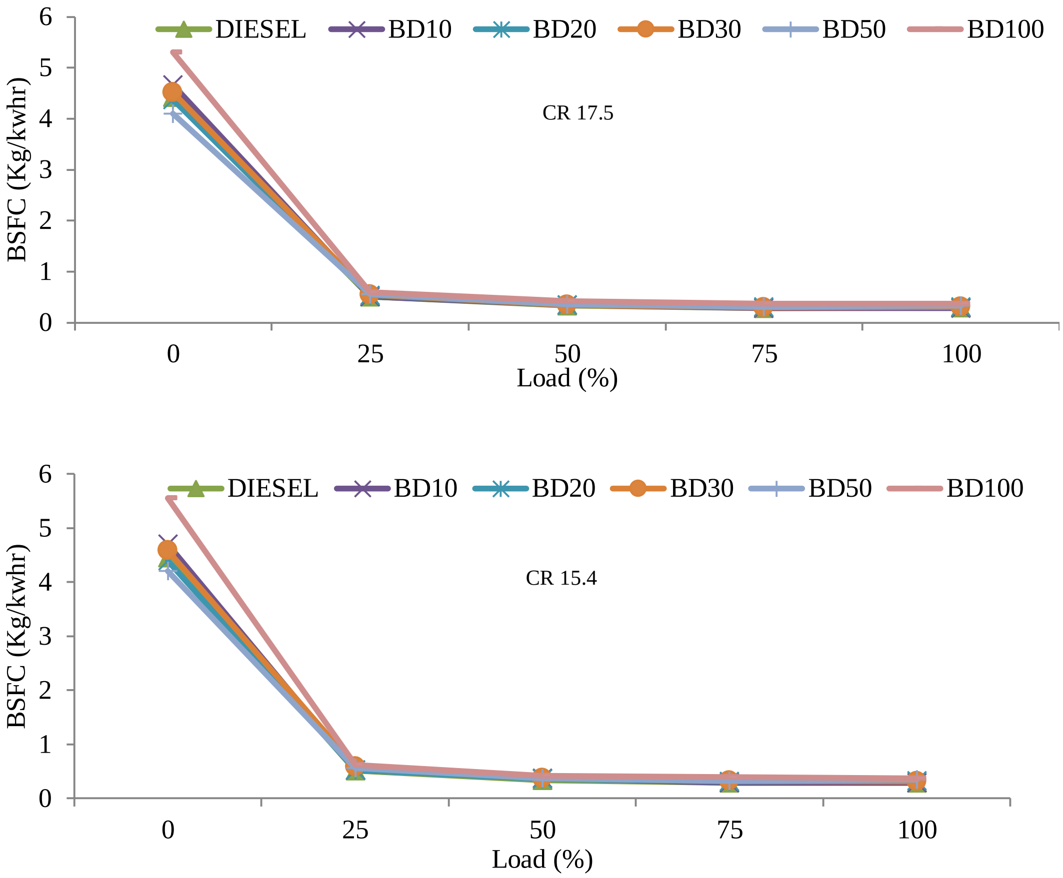


Fig. 4 Load versus BSFC for CR 15.4 and 17.5

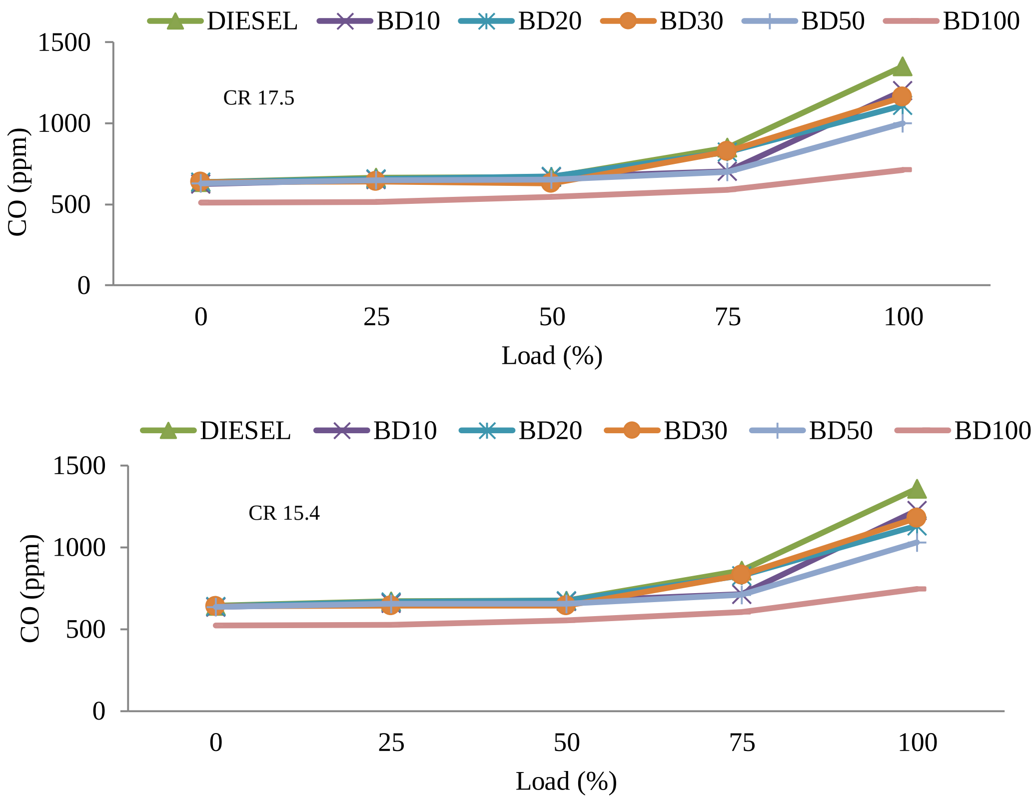


Fig. 5 Load versus CO at CR 15.4 and 17.5

Figure 6 indicates that the effect of loads on the CO_2 emissions for the CR 15.4 and 17.5. The figure indicates that, with an increase in loads, CO_2 emissions are increased. Also, for most of the loads, the CO_2 emissions for blended fuels were found to be more than D100. Low carbon percentage in the same amount of fuel burned is caused by the presence of O_2 in KOME molecules. Consequently, mixed fuel emits more CO_2 [18, 19].

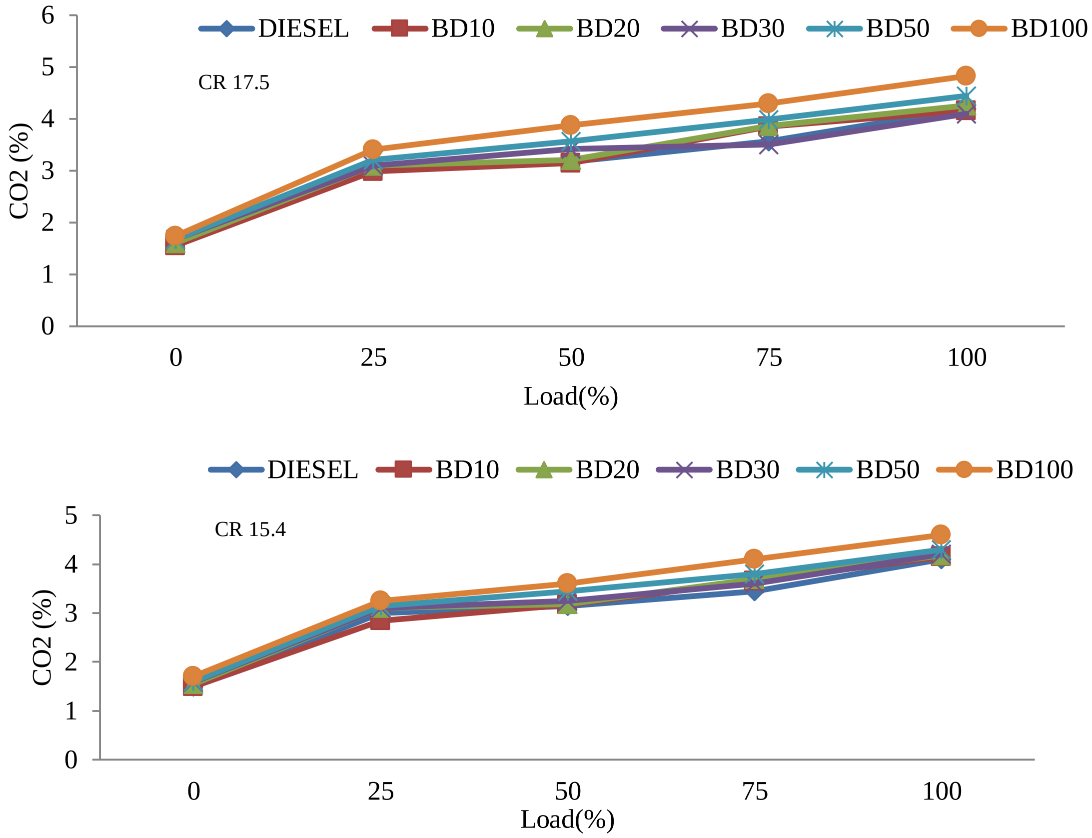


Fig. 6 Load versus CO_2 at CR 15.4 and 17.5

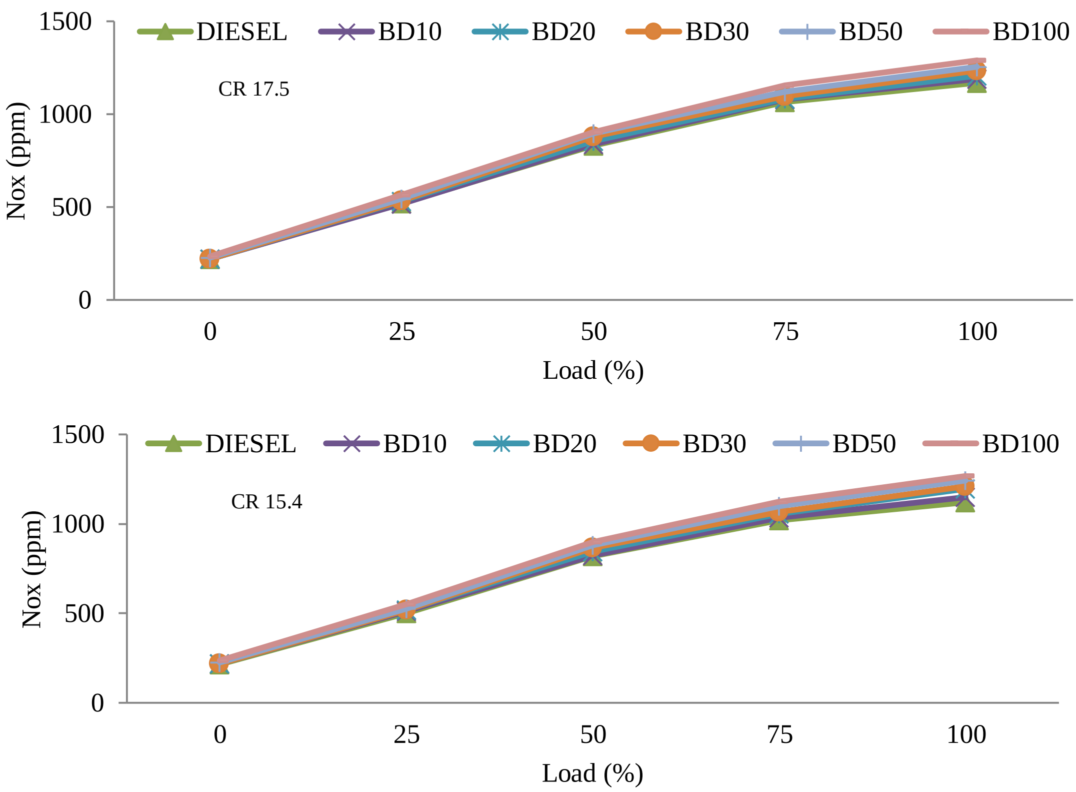


Fig. 7 Load versus NO_x at CR 15.4 and 17.5

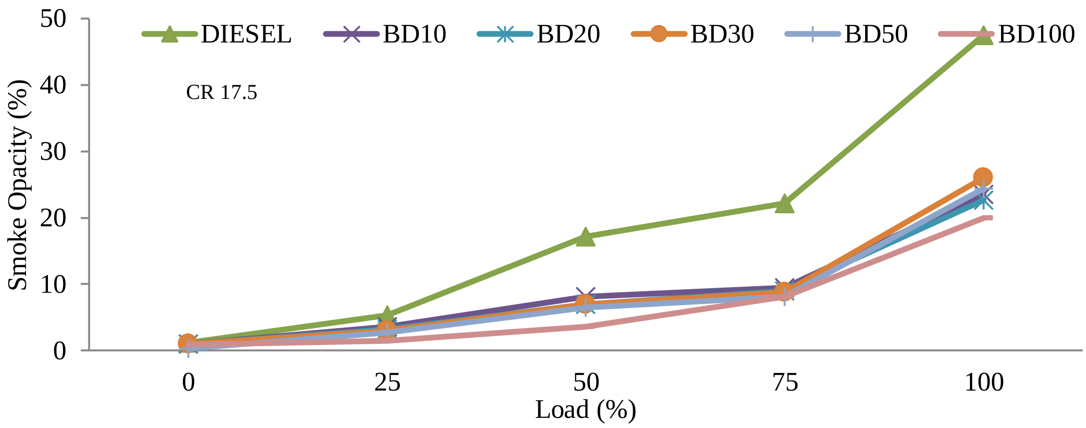
Figure 7 indicates the effect of NO_x emissions at various loads for the compression ratio 15.4 and 17.5. The figure indicates that the NO_x emission is increased with the increase of load and CR. The emission of NO_x depends upon the combustion chamber temperature and the presence of oxygen, with the increase in CR and load, temperature increases, which leads towards higher emissions of NO_x. Also, for most of the loads, the NO_x emissions of D100 were lower than blended fuels. The O_2 present in the KO molecules causes elevated NO_x levels for the mixed fuels [20].

Raheman et al. [12] have tested pure esters of KO and 20, 40, 60 and 80% ester with diesel in a single-cylinder diesel engine. For all tests, NOx emissions were lower than diesel. As compared to diesel, a 26% diminishment in NOx was obtained for biodiesel and its mixes. He has mentioned that the improvement in the combustion process with the addition of KOME with diesel cause a reduction in NOx emissions for blended biodiesel fuels. While, Srivastava et al. [17] have obtained 12% higher NOx emissions for KOME blended fuel as compared with diesel. They have tested pure esters of KO and 5, 10, 20 and 30% esters of KO with diesel in CI engine. With an increase in load for all fuels under nearly all loading situations, he has acquired increased NOx emissions; the NO_x emissions for the ester of KO and its blends with diesel were higher than pure diesel.

The effects of load on smoke opacity are indicated in Figure 8. KO mixed fuels have less smoke opacity than D100. As oxygen in the KOME improves combustions therefor, for blended fuels, oxygen reacts with carbon and is converted into CO or CO_2, which reduces the smoke [21, 22]. The smoke emissions were higher at high loads which is due to more fuel required at high loads because incomplete combustion of fuel occurred, so smoke opacity increased. The lower smoke at higher CR was due to high pressure, temperature and better oxidation environment at higher CR.

The other group of researchers has obtained similar results for other feedstock. H. G. How et al. [23] have tested various blends of coconut biodiesel (10, 20, 30 and 50%) with diesel in single-cylinder diesel engines. It was found that the amount of smoke decreased as the fuel mix's biodiesel content increased. For example, with a high load of 0.86 Mpa, smoke decreases by 5.4%, 15.1%, 20%, and 52.4% for B10, B20, B30, and B50 compared to diesel fuel.

Chauhan et al. [6] have obtained similar patterns during the testing of various blends (5%, 10%, 20%, 30% and 100%) of KOME with diesel. For most load conditions, Smoke opacity increased for all fuels as the load rose. Also, the smoke opacity was reduced by increasing the KOME blending with diesel. At full load, for pure diesel and pure KOME, the emission of smoke was 90% and 65%, respectively.



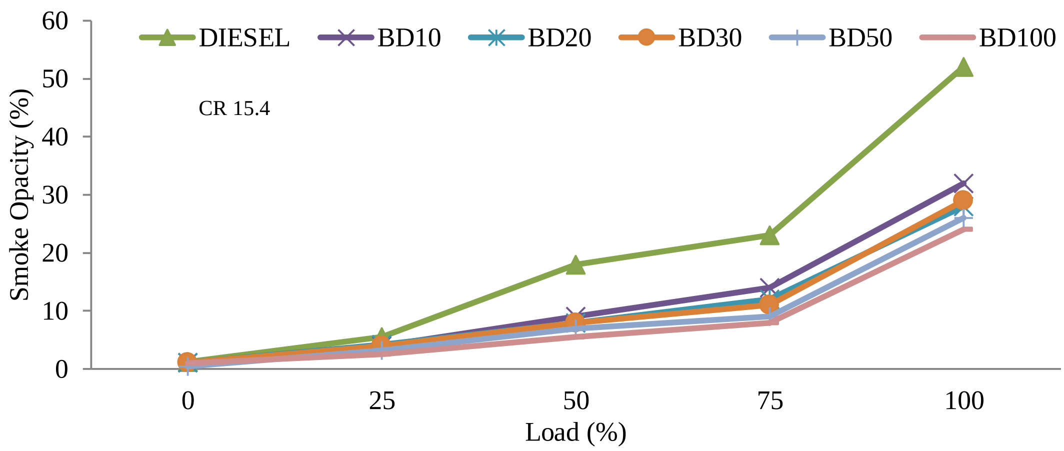


Fig. 8 Load versus Smoke at CR 15.4 and 17.5

5. Conclusion

In this research, the diesel engine analysis for blended KOME at different CR was compared with D100. It is concluded that the engine shows better performance at a higher CR (17.5). The smoke and CO emissions are lower at higher CR. The highest BTE for blended fuel is 30.31% for BD10 at 100% load with 17.5 CR. Lower BTE and greater BSFC are noted for higher blends and lower CR. For higher CR, there is a larger BTE and a lower BSFC. The blends of KOME show better emission results than diesel fuel. At CR 17.5, at 100% load, CO emission was reduced by 13.04 % and CO_2 emission was raised by 14.7 % on average. Smoke opacity is decreased by 50.75%, and NO_x emission is raised by 6.4 % on average as compared to D100.

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