

Effect of Compression Ratio on the Performance and Emission Characteristics of Blends of Lard Oil Methyl Ester and Diesel on C I Engine

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Abstract In the present study, Lard oil methyl ester (LOME) has been extracted from pig fats by base-catalyzed transesterification with methanol in the presence of sodium hydroxide (NaOH) as catalyst. The effect of LOME addition to pure diesel on the performance and emission characteristics of direct injection diesel engine has been experimentally investigated by varying the compression ratio at a constant load. The experimental test results showed that the addition of LOME to diesel decreased the brake thermal efficiency of the engine by 3% and increased the specific fuel consumption by 3% compared to pure diesel. But for B20 blend, carbon monoxide (CO), hydrocarbon (HC), oxides of nitrogen (NO_x) and smoke emission are decreased by 20%, 4%, 14%, and 3% respectively as compared to pure diesel at full load of the engine.

Keywords Lard Oil Methyl Ester, Diesel, C I Engine, Emission

1. Introduction

The production and use of fossil fuel in internal combustion engines causes environmental pollution, such as rise in carbon dioxide levels in the atmosphere [1]. The combustion of petroleum leads to emission of CO, SO₂, NO_x etc resulting in global warming, which threaten wild and human life, impacts on the environment and human health. Hence research is going on to find an alternative for diesel fuel. Biodiesel is a liquid biofuel obtained by chemical processes from vegetable oils or animal fats and an alcohol that can be used in diesel engines alone or blended with diesel oil [2]. Different animal fats like pork lard, beef tallow, chicken fat, yellow grease and brown grease are used for biodiesel production [3]. Biodiesel is biodegradable and non-toxic and has low emission profiles as compared to petroleum diesel [4]. Hence biodiesel research has become more prominent research.

Biodiesel can be obtained through the esterification process. During this process raw oil is tested for free fatty acid (FFA) content using titration method [5]. If FFA is less than 4% then directly transesterification can be carried out. If it is greater than 4%, more NaOH is added to convert oil to methyl ester. Esterification process is done by employing methanol/ethanol in presence of acid as homogeneous catalyst, among which H₂SO₄ exhibited very promising

result [5].

In transesterification reaction, NaOH and Methanol/Ethanol are mixed in a conical flask till all the methanol/Ethanol dissolves. Oil is heated in a round bottom three necked flask. Oil is heated up to the boiling point of Methanol/Ethanol. The mixture of methyl alcohol and NaOH is added to oil in the round bottom flask at that particular temperature. Heating is done for 2 hours and while heating mixture is continuously stirred by magnetic stirrer. Later this is transferred to a separating funnel and it is kept for one day for complete separation of biodiesel from glycerin. Then the methyl ester is separated from the conical flask and subjected to water washing. A small quantity of hot water is added and the biodiesel is water washed. This water washing is done till the mixture becomes clear. Heating the mixture will result in evaporation of water from the fuel sample. This end result is methyl ester which can be used as a fuel in IC engines.

2. Experimental Details

In this work biodiesel is produced and its properties are measured. Experiments are conducted in VCR engine for different blends like diesel B10, B20 and B30 for performance and emission characteristics at three compression ratios at a constant speed of 1500 rpm.

2.1. Transesterification

The biodiesel is produced by transesterification method which was carried out using a round bottom flask of 1 litre capacity, equipped with thermostat, mechanical stirrer, sampling outlet and condensation systems. A freshly

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prepared 300 ml methanol and 6.5 grams of sodium hydroxide solution are taken in a separate flask. 1000 ml of lard oil is heated to 65°C in the round bottom flask and the solution is mixed with the lard oil which is heated to 65°C. Now the reaction takes place for 2 hours with same temperature of 65°C. After 2 hours, the solution is taken in a separating funnel and kept for minimum 15 hours for proper settling of glycerin. The glycerin collected at the bottom of the funnel is taken out and lard oil methyl ester is washed with hot water to remove soap and glycerin content from the lard oil methyl ester till a clear lard oil methyl ester is obtained.

2.2. Properties of Fuel Samples (Diesel and Blends of LOME)

Table 1 shows the properties of fuel samples. Higher Calorific value is found by Bomb calorimeter apparatus. Density is found by using hydrometer. Cannon Fenske Viscometer is used to measure the Kinematic Viscosity. Flash and fire points are found by using Cleveland open cup apparatus.

Table 1. Properties of Diesel and blends of LOME

Properties	Higher Calorific value (kJ/kg)	Density (kg/m ³)	Kinematic Viscosity @ 40°C (cSt)	Flash Point (°C)	Fire Point (°C)
ASTM Standards	D 240	D-4052	D445	D92-05a	D92-05a
Diesel	46363	712.6	2.63	56	58
B10	43630	716.1	2.98	76	78
B20	40902	726.3	3.21	80	82
B30	38170	729.4	3.41	84	86
B100	29980	759.5	4.12	172	174

It is observed that the calorific value of LOME is less than diesel fuel. Viscosity of the blend increases as the percentage of LOME increases in the fuel sample. Density, flash and fire points also increase as the percentage of LOME increases in the fuel sample.

2.3. Engine Setup

The Engine setup consists of a single cylinder, four stroke, water cooled variable compression ratio diesel engine connected to an eddy current type dynamometer for loading. A tilting cylinder block arrangement is used for varying the compression ratio without stopping the engine and without altering the combustion chamber geometry. Temperature sensor arrangements are made in the measurement of exhaust gas inlet and outlet temperatures, water jacket and calorimeter water. The exhaust gas emissions are measured using an exhaust gas analyser and smoke opacity is measured using a smoke meter.

3. Results and Discussion

The experiments were conducted at a constant speed of 1500 rpm for three different compression ratios of 16, 17 and 17.5 at an injection pressure of 200 bar with diesel and LOME blends (B10, B20 and B30). Mass flow rate, load, emissions and smoke opacity readings were recorded for various loads. Engine performance parameters like brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) were calculated.

3.1. Performance Characteristics

3.1.1. Brake Specific Fuel Consumption (BSFC)

Figure 1 shows the variation of BSFC with respect to compression ratio for diesel and LOME blends (B10, B20 and B30) for 12 kg load. From the graph it is observed that, as compression ratio increases BSFC decreases. This is due to the reason that at higher compression ratio the power generated is high with respect to fuel consumption [6]. And also as the percentage of biodiesel in the blend increases, BSFC increases. It is due to the lower calorific value of biodiesel and its blends compared to diesel, more amount of fuel is required to produce the same power output [7]. Here among the three compression ratios, BSFC is minimum for a compression ratio of 17.5. Also as percentage of LOME in the blend increases BSFC also increases. From compression ratio 17 to 17.5 for diesel, BSFC decreases by 1%.

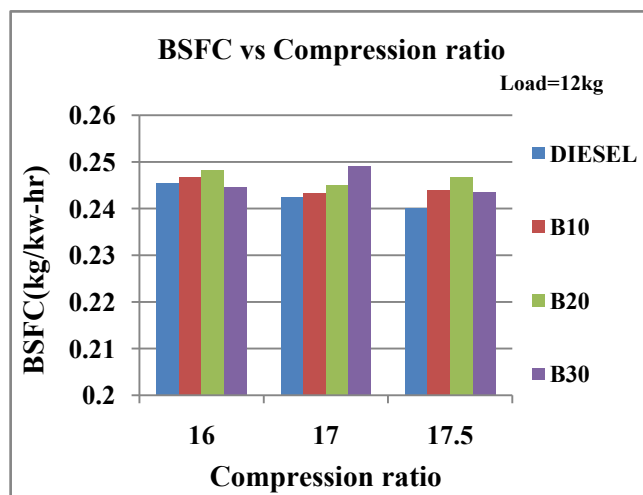


Figure 1. Variation of BSFC with Compression ratio for different fuel samples

3.1.2. Brake Thermal Efficiency (BTE)

Figure 2 indicates the variation of BTE with respect to compression ratio for diesel and LOME blends (B10, B20 and B30) at a load of 12 kg. It is observed that as compression ratio increases BTE also increases. This is due to the increase in compression ratio ensures better air-fuel mixing and faster evaporation and leads to complete combustion [8]. But as biodiesel in blend increases, BTE decreases. This is due to combined effect of its lower heating value and increase in

fuel consumption [9]. BTE is maximum at compression ratio 17.5. 2.4% increase in BTE is observed when compression ratio is increased from 17 to 17.5.

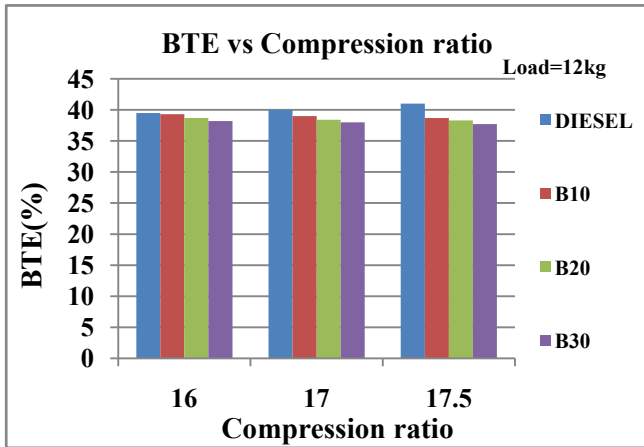


Figure 2. Variation of BTE with Compression ratio for different fuel samples

3.2. Emission Characteristics

3.2.1. Hydro Carbon (HC)

Figure 3 shows variation of HC with respect to compression ratio for diesel and LOME blends (B10, B20 and B30) at a load of 12 kg. It is observed that as compression ratio increases, emission of hydrocarbon decreases. This is due to the increase in air temperature at the end of compression stroke, enhancement in combustion temperature and reduction in charge dilution leads to complete combustion and reduction in hydrocarbon emissions [10]. And as percentage of biodiesel in blend increases, emission of HC also decreases. The HC emission is least at compression ratio 17.5 among the three compression ratios. For diesel fuel HC is decreased by 3.5% at a compression ratio of 17.5.

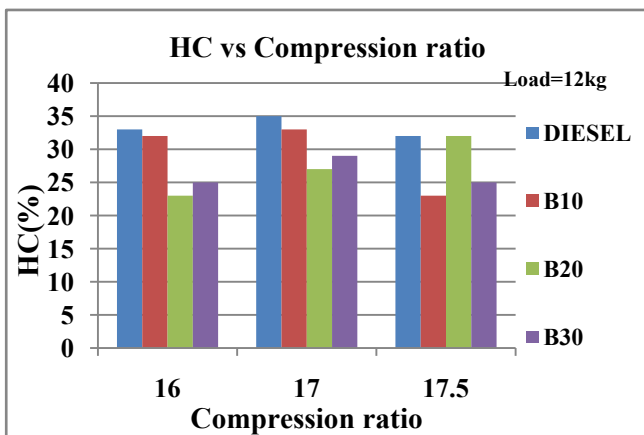


Figure 3. Variation of HC with Compression ratio for different fuel samples

3.2.2. Carbon Monoxide (CO)

The variation of CO with respect to compression ratio for diesel and LOME blends (B10, B20 and B30) at a load of 12

kg is shown in Figure 4. It is observed that as compression ratio increased, emission of CO is decreased. This is due to, at high compression ratio better combustion occurs [6]. Also as percentage of biodiesel in the blend increased, emission of CO is decreased. At a compression ratio of 17.5 the values of CO emission are a minimum among the three compression ratios.

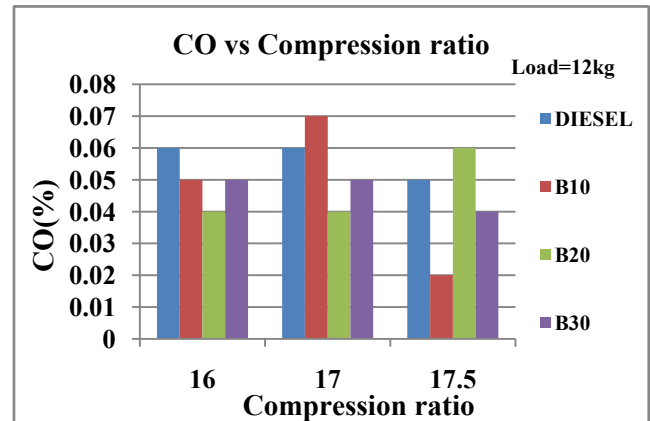


Figure 4. Variation of CO with Compression ratio for different fuel samples

3.2.3. Carbon Dioxide (CO₂)

Figure 5 shows the variation of CO₂ with respect to compression ratio for diesel and LOME blends (B10, B20 and B30) at a load of 12 kg. It is observed that as compression ratio increases, emission of CO₂ decreases. This is due to the better combustion [6]. Also as percentage of biodiesel in blend increases, the carbon dioxide emission decreases. At a compression ratio of 17.5 for B10 fuel sample the CO₂ emission decreases by 17.7% compared to the emission at a compression ratio of 17.

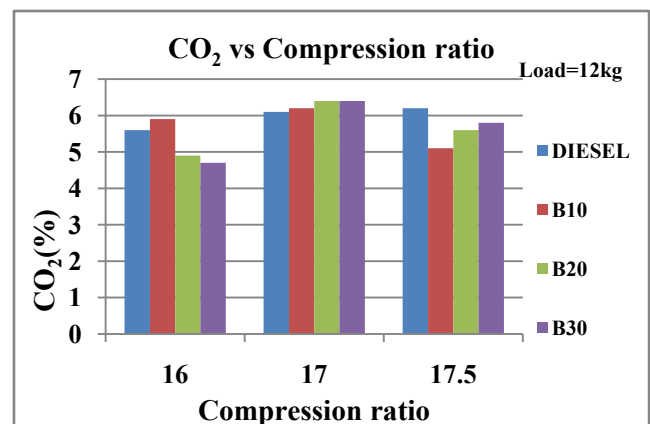


Figure 5. Variation of CO₂ with Compression ratio for different fuel samples

3.2.4. Oxides of Nitrogen (NO_x)

NO_x is formed during combustion because of high temperature inside the cylinder. Figure 6 shows the variation of NO_x with respect to compression ratio for diesel and LOME blends (B10, B20 and B30) at a load of 12 kg. It is observed that as compression ratio increases, emission of

NO_x also increases. Also as percentage of biodiesel in blend is increased, emission of NO_x also increased. This is due to the availability of excess oxygen in the biodiesel. Hence highest NO_x is observed at a compression ratio 17.5. For diesel NO_x increases by 16.4% at a compression ratio of 17.5 compared to that at compression ratio of 17.

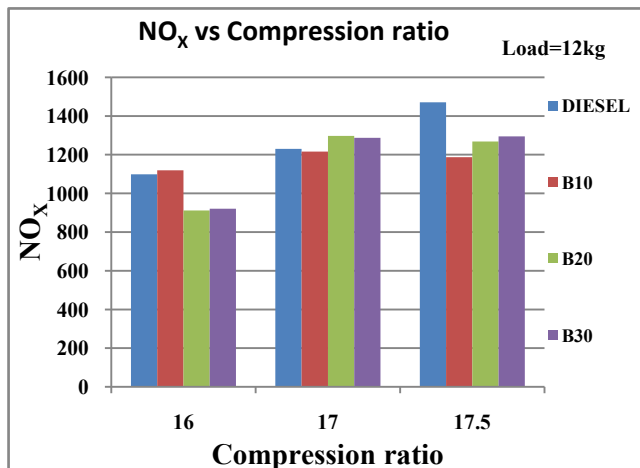


Figure 6. Variation of NO_x with Compression ratio for different fuel samples

3.2.5. Smoke Opacity

Figure 7 shows variation of smoke opacity with respect to compression ratio for diesel and LOME blends (B10, B20 and B30) at a load of 12 kg. It is observed that as compression ratio increases, smoke opacity decreases for most of the loads and the blends. But as percentage of biodiesel in blend increases smoke opacity also increases. At a compression ratio of 17.5 the emission of smoke will be less than that at other compression ratios. At a compression ratio of 17.5, smoke opacity value for B20 is decreased by 2.5% as compared to that obtained at a compression ratio of 17.

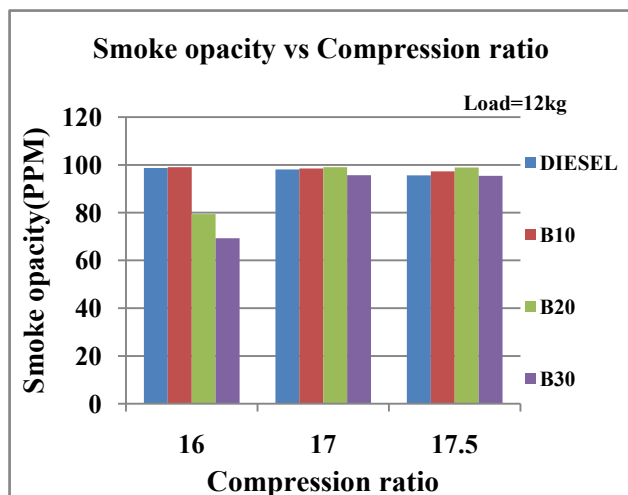


Figure 7. Variation of Smoke opacity with Compression ratio for different fuel samples

4. Conclusions

The following conclusions may be drawn from the present study.

- The performance and emission characteristics are better for LOME blends at a compression ratio of 17.5.
- As the compression ratio increases the BTE increases but BSFC decreases.
- As the percentage of LOME in the blend increases, BSFC increases but BTE decreases.
- As compression ratio increases, emissions of HC, CO, CO₂ and smoke opacity decrease but NO_x increases.
- As the percentage of LOME in blend increases, emissions of HC, CO and CO₂ decrease but NO_x and smoke opacity increase.

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REFERENCES

- [1] Ivana B. Bankovic-Ilic, Ivan J. Stojkovic, Olivera S. Stamenkovic, Vlada B. Veljkovic, Yung-Tse Hung, 2014, Waste animal fats as feedstocks for biodiesel production, *Renewable and Sustainable Energy Reviews*, 23, 238-254.
- [2] S. D. Romano and P. A. Sorichetti, *Dielectric Spectroscopy in Biodiesel Production and Characterization*, Green Energy and Technology, London, Spriger-Verlag, 2011. (DOI-10.1007/978-1-84996-519-4_2).
- [3] J.M. Encinar, N. Sanchez, G. Martínez, L. Garcia, 2011, Study of biodiesel production from animal fats with high free fatty acid content, *Bioresource Technology*, 102, 10907-10914.
- [4] L.C. Meher, D. Vidya Sagar, S.N. Naik, 2004, Technical aspects of biodiesel production by Transesterification, *Renewable and Sustainable Energy Reviews*, 10, 248-268.
- [5] Rajat Chakraborty, Abhishek K. Gupta, Ratul Chowdhury, 2013, Conversion of slaughterhouse and poultry farm animal fats and wastes to biodiesel: Parametric sensitivity and fuel quality assessment, *Renewable and Sustainable Energy Reviews*, 29, 120-134.
- [6] Rahul Krishnaji Bawane, S.V. Channapattana, Nilima Baliram Gadge, Sandip M. Ingole, 2014, Experimental Investigation of Performance Characteristics of Calophyllum Inophyllum Biodiesel in CI Engine by Varying Compression Ratio, *International Journal of Engineering and Advanced Technology*, 3 (5), 179-183. ISSN: 2249 – 8958.

- [7] Jalpit B. Prajapati, Parth R. Panchal, Tushar M. Patel, 2014, Performance and emission characteristics of C.I. engine fuelled with diesel-biodiesel blends, IOSR Journal of Mechanical and Civil Engineering, 11,114-121. e-ISSN: 2278-1684, p-ISSN: 2320-334X.
- [8] R. Silambarasan, R. Senthil, G. Pranesh, P. Mebin Samuel, M. Manimaran, 2015, Effect of compression ratio on performance and emission characteristics of biodiesel blend operated with VCR engine, Journal of Chemical and Pharmaceutical Sciences, 23-25. ISSN: 0974-2115.
- [9] Peter S K F, Ganswindt R, Neuner H P, Weidner E, 2002, Alcoholysis of triacylglycerols by heterogeneous catalysis. Eur J Lipid Sci Technology, 104 (6), 324–330.
- [10] Freedman B, Pryde E H, Mounts T L, 1984, Variables affecting the yields of fatty esters from transesterified vegetable oils. J Am Oil Chem Soc, 61 (19), 1638–1643.