ISSN 2395-1621

Emissions and Performance Evaluation of DI CI - VCR Engine Fuelled with Honne oil Methyl Ester / Diesel Blends

#1S V Channapattana, #2Kantharaj C, #3V S Shinde, #4Abhay A Pawar, #5Prashant G Kamble

[1]Asst. Professor, Mechanical Engineering Department, Rajarshi Shahu College of Engineering, Pune 411033, India [2] PG Student,
[3]Asst. Professor, Trinity College of Engineering and Research, Pune 411048, India
[4]Professor and Head, Mechanical Engineering Department, Rajarshi Shahu College of Engineering, Pune 411033, India
[5]Professor , Industrial and Production Engineering Department, PDA College of Engineering, Gulbarga 585102, India

ABSTRACT

The present work investigates the emission and thermal performance of DI CI variable compression ratio engine using blends of biodiesel and standard diesel as a fuel at compression ratios of 15,16,17 and 18. The biodiesel derived from non edible Calophyllum Inophyllum linn oil is used on the engine. The blends of biodiesel and diesel used were B20, B40, B60, B80 and 100% biodiesel. At 18 CR the brake thermal efficiency of the engine operated with 100% biodiesel is 8.9% less than Diesel and the brake specific fuel consumption for biodiesel found to be more than that of diesel. There is major reduction in Carbon monoxide and Hydrocarbon emissions with 100% biodiesel as a fuel compared to diesel at compression ratio of 18.

Keywords: **Honne oil methyl ester; VCR engine;Brake thermal efficiency; Brake specific fuel consumption; carbon monoxide; nitrogen oxides.**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

Due to ever increasing demand for fossil fuels, several researchers studied the effect of different renewable alternative sources of energy on Engines. Biodiesel is one among them. Biodiesel are of two types: one derived from edible oil and other from non-edible oil source. Due to demand of edible oil for domestic purpose, non edible oil is preferred for Biodiesel production. Net carbon [1] emission into the atmosphere is very less with biodiesel compared to that of fossil fuels. One of the prominent sources of non edible oil is the oil derived from seeds of Calophyllum Inophyllum linn which is commonly known as Honne oil or Undi oil in India. The viscosity of the Honne oil is more compared to Diesel fuel. The viscosity is reduced by removing the glycerol in the Honne oil by the process of transesterification. The transesterification is the process of chemically reacting triglycerides with methanol in presence of sodium hydroxide as a catalyst. The Biodiesel obtained by transesterification of Honne oil is called Honne oil Methyl ester. Even though, the effects of Injection Pressure and Injection timing on the diesel engine using Honne oil are reported, literature survey reveals that thermal performance and emission characteristics with 100 %

	Nomenclature		
HnOME	Honne oil methyl esters	HC	Unburned hydrocarbon
B20	20 % biodiesel and 80% mineral diesel by volume	CO	Carbon monoxide
BTE	Brake thermal efficiency	CO_2	Carbon dioxide
BSFC	Brake specific fuel consumption	NO_X	Oxides of Nitrogen
HSU	Hartridge smoke unit	CI	Compression Ignition
IMEP	Indicated Mean Effective Pressure	EGT	Exhaust gas temperature

esterified Honne oil by varying compression ratio on CI engine are not yet reported.

Based on the study of oil [2] extraction and bio-diesel production process from seeds of Calophyllum inophyllum (honne), it was concluded that it may works as a sustainable feedstock for biodiesel production equivalent to fossil fuel as per ASTM 6751. Biodiesel [3] produced from the seeds of Honne by in-situ transesterification reaction process found that the biodiesel fraction from oil content was 74.5 %. The performance and emission of palm oil, [4] Jatropha curcas and Calophyllum inophyllum biodiesel was reviewed. Palm oil is one of the most efficient oil bearing crops. But the competition between edible oil as food with fuel makes edible oil not an ideal feedstock for biodiesel production. Therefore, attention was shifted to non-edible oil like Jatropha curcas and Calophyllum inophyllum. Biodiesel produced from Calophyllum inophyllum oil by pre-treatment [5] with phosphoric acid modified benzeolite in acid catalyzed transesterification and preceded by using alkali catalyst potassium hydroxide was tested for its fuel properties, which were close to diesel.

The performance study was conducted on a DI diesel engine operated with neat Diesel and Honne oil, result shows that the BTE of Honne oil slightly lower compared to Diesel [6]. EGT of Honne oil was higher by 50^{o}C compared Diesel. CO, HC and smoke emissions of Honne oil were little higher compared to Diesel. Using preheated honne oil to 60°C, [7] BTE, EGT, NOx emissions were more compared to unheated honne oil. The emissions such as smoke opacity, CO and HC of preheated honne oil were reduced.

Blends of Diesel and esterified soyabean [8] oil tested on a single cylinder diesel engine at two different CR’s of 16 and 18. BTE found to increase as the CR in increased. [9 - 12] Studies were conducted on CI engine by varying CR using different biodiesel-diesel blends. It was found that engine torque increases for all the blends as the CR increases. The BSFC decreases as the CR is increased. As [13] CR increase BTE was considerably increased for all the blends. But the blend used was only up to 50%.

In this study, Honne oil methyl esters (HnOME) and its blends with diesel is chosen as a fuel for variable compression ratio engine. The various blends of HnOME and standard diesel fuel are prepared. Then the investigation is carried out on the performance and emission characteristics at compression ratios of 15, 16, 17, and 18.The properties of the fuels used in the experiments are listed in the Table 1. Also experiments are conducted with neat diesel for the purpose of comparison. The variation of thermal performance parameters and emission constituents are studied with respect to change in compression ratio at full load..

Table 1. Engine details

Model and Make	Kirloskar and TV1
No. of cylinder, Cycle of operation	Single, Four stroke
Bore and stroke, Rated Power	87.5 mm and 110 mm , 3.5 kW at 1500 rpm
Compression ratio	17.5, Modified to work in range of 12 to 18
Dynamometer	eddy current, water cooled, with loading unit

Table 2. Properties of diesel and different biodiesel blends

Properties	**Ref. Std. ASTM6751**	**Diesel**	**B100 (HnOME)**	**B80**	**B60**	**B40**	**B20**
Density (kg/m^3)	D1448-1972	830	889	872	860	852	840
Viscosity at 40^{o}C (cSt)	D445-73	2.9	5.2	4.6	4.4	4.1	3.6
Cetane Number	D613	51	52.03	51.8	51.4	51.4	51.3
Calorific value (MJ/kg)	D6751	42.5	38.55	40.1	41	41.18	41.3
Ash Content (%)	D482	0.10	0.51	-	-	-	-
Flashpoint (^{o}C)	D93	65	170	146	130	108	76
Fire Point (^{o}C)	D93	78	182	176	158	142	101
Cloud point (^{o}C)	D2500	-	4	-	-	-	-

II. EXPERIMENTAL SETUP

The CI Direct Injection engine used for experimentation with necessary instrumentation and with computer interface is shown in Fig.1. The detailed specification of the engine is shown in Table 1.The engine has provision to change compression ratio (CR) by tilting block arrangement. The tilting cylinder block arrangement consists of a tilting block with six allen bolts, a compression ratio adjuster with lock nut and compression ratio indicator. For setting a chosen compression ratio, the allen bolts are to be slightly loosened. Then, the lock nut on the adjuster is to be loosened and the adjuster is to be rotated to set a chosen compression ratio by referring to the compression ratio indicator and to be locked using lock nut. Finally all the Allen bolts are to be tightened gently. When the CR is to be reduced the block is tilted so that the clearance volume increases and swept volume remains a constant.

2.1. Experimental methodology

The engine is started by using standard diesel and when the engine reaches the operating temperature, 25% load is applied. The warm up period ends when cooling water temperature is stabilized at 60^{o}C. Then the load is applied gradually to 50%, 75% and 100% .The tests are conducted at the rated speed of 1500 rpm. In every test, volumetric fuel consumption and exhaust gas emissions such as CO, HC, NOx, CO_2 and O_2 are measured. From the initial measurement BTE, SFC, BP, IMEP, mechanical efficiency and EGT with respect to compression ratios 15:1, 16:1, 17:1 and 18:1 for different blends are recorded. At each operating conditions, these data are processed and stored in personal computer for further processing of results. The same procedure is repeated for different blends of Honne oil methyl esters. The properties of the diesel fuel and the bio diesel blends are summarized in Table 2.

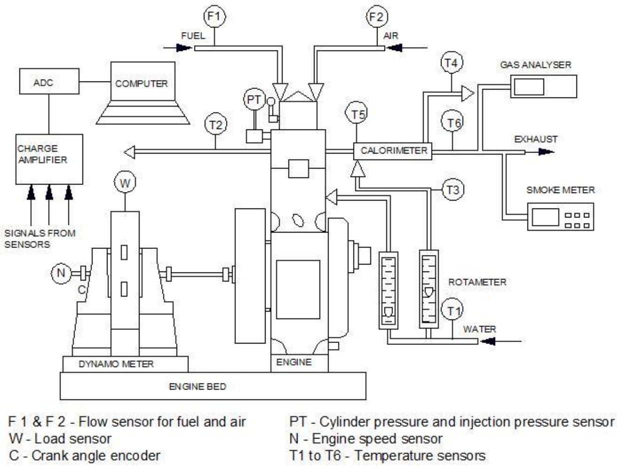


Fig.1.1. Schematic diagram of the Experimental Set up

III. RESULTS AND DISCUSSION

3.1 Thermal Performance

The thermal performance parameters considered in the present study are BTE, BSFC, EGT, BMEP, HEG. The effect of compression ratio on the above performance parameters are studied at full load of 12 kg and injection pressure of 210 bar. The variation of the performance parameters with respect to the compression ratio is plotted as shown in Fig.3.1 to Fig.3.5.

3.1.1. Brake Thermal Efficiency (BTE)

It can be noted from Fig.3.1 that as the blend percentage increases the Brake thermal efficiency decreases. This may be because of deterioration in combustion due to higher viscosity of biodiesel. But as the compression ratio increases BTE increases for honne bio diesel blends and reaches maximum value at the compression ratio of 18.With the increase in CR from 15 to 18, the BTE increased approximately up to 7 % for all fuels. At 18 CR the BTE of the engine operated with Honne biodiesel is 8.9% less than Diesel.

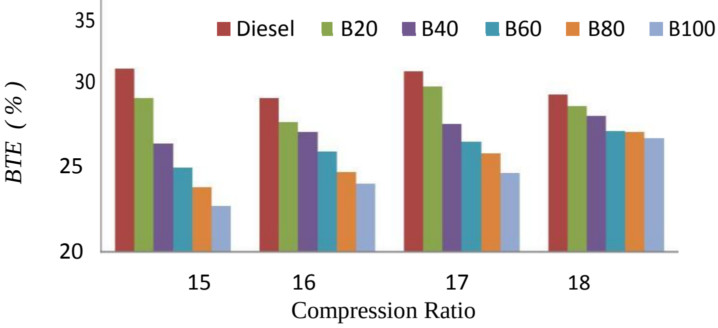


Fig.3.1. Variation of Brake thermal efficiency with CR

3.1.2. Brake Specific Fuel consumption (BSFC)

Fig. 3.2 shows that the BSFC increases with the increase in percentage of biodiesel in the blend. This may be due to the lower calorific values of biodiesel and short delay period. As CR increases from 15 to 18, BSFC decreases for all biodiesel blends and for pure biodiesel. It is seen that the consumption of pure Honne biodiesel is about 27% more at CR of 15 while that at CR of 18 is about 11% more. The BSFC is found to be the least at 18 CR because at higher CR's complete combustion of fuel takes place due to high temperature of compressed air.

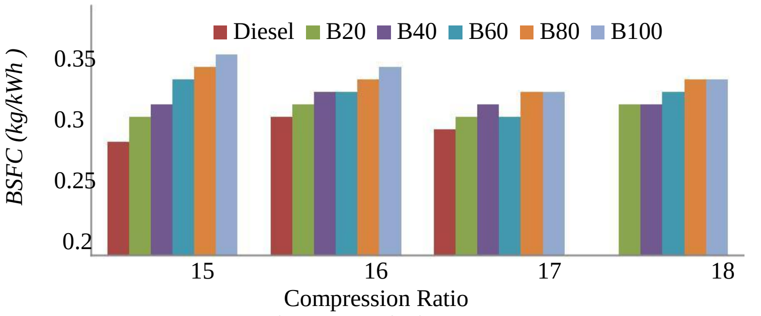


Fig.3.2 Variation of Brake specific fuel consumption with CR

3.1.3. Brake Mean effective pressure (BMEP)

It can be observed from the Fig.3.3 that CR does not have a significant effect on BMEP. It is also observed that the use of different H o n n e biodiesel-diesel blends does not have much effect on BMEP. The Effective pressure characteristic of Diesel and B 20 blends exhibited are approximately the same.

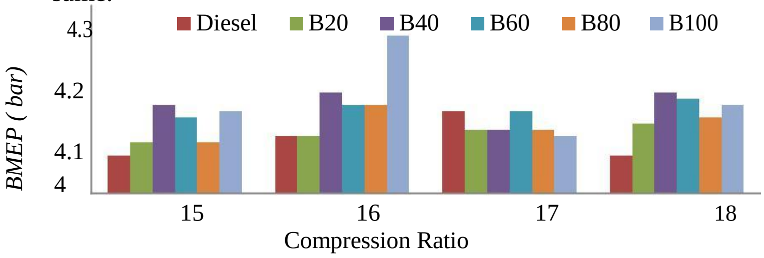


Fig. 3.3 Variation of Brake mean effective pressure with CR

3.1.4. Heat equivalent of exhaust gas (HEGas)

It can be observed from the Fig.3.4 that there is nospecific trend of variation of HEGas with biodiesel content in the blend. However, at most of the CRs it is less for biodiesel than Diesel. This is due to lower heat released in combustion of biodiesel due to its lower calorific value. The values of HEGas for Diesel at CRs 15,16,17,18 are 27.8%, 24.92%, 25.92% and 24.08% and for biodiesel are 24.31%, 24.32%, 31.48% and 21.71% respectively.

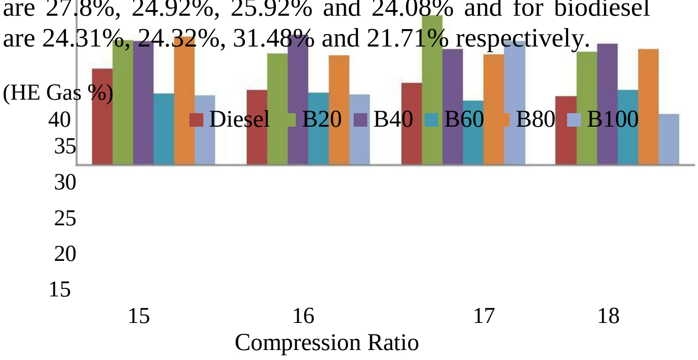
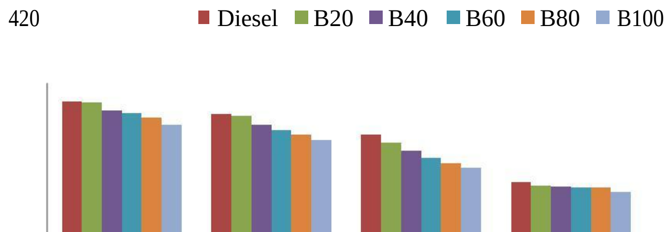


Fig.3.4. Variation of Heat Equivalent of Exhaust Gas with CR

3.1.5. Exhaust Gas Temperature (EGT)

It can be seen from the Fig.3.5 that EGT decreases with the increase in CR for all the fuels. It is observed that EGT reduces with the increase in biodiesel percentage in blend. The rate of EGT drop is almost the same at different CRs for all fuels. The EGT reduces up to 16% for all fuels as the CR increases from 15 to 18. At CR of 18, the values of EGT for Honne biodiesel, B80, B60, B40, B20 and Diesel are found to be 343.77°C, 346.99°C, 347.25°C, 345.67°C, 347.96°C and 350.75°C respectively indicating that EGT at higher CRs for blends are closer to Diesel.



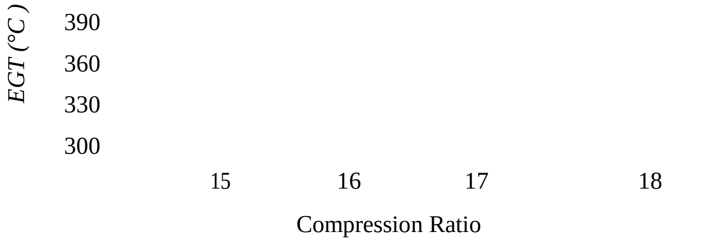


Fig.3.5. Variation of Exhaust Gas Temperature with CR

3.2. *Emission Characteristics*

The variation of emission constituents with compression ratio considered are Carbon monoxide (CO), Unburned Hydrocarbon (HC), Carbon dioxide (CO2), Oxides of Nitrogen (NOx), Smoke intensity (HSU). The variations of exhaust emission constituents at different values of CRs at 15, 16, 17 and 18 with a constant rated load of 12kg and IP of 210bar is presented in Figures 3.6 to 3.10.

3.2.1. Carbon monoxide (CO)

It is seen from the Fig.3.6 that as the CR is increased, the CO emission is reduces for all the fuels. This is due to better combustion of fuel at higher CR due to high air temperature in the cylinder. It can also be observed that CO emissions are higher at low CRs, and lesser at higher CRs. CO emissions are lesser for blends compared to Diesel. CO emissions are higher for blends at low CR.CO emissions are 64% less for pure Honne biodiesel as compared to Diesel at CR of 18.

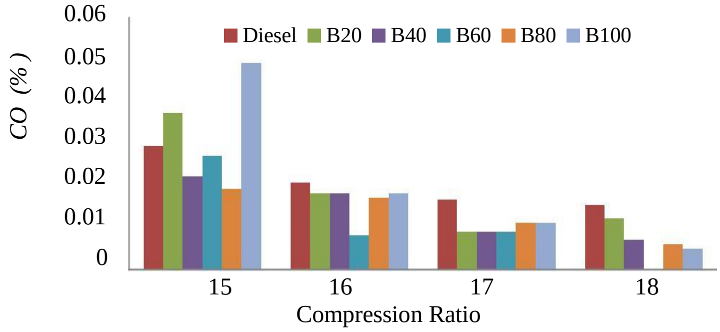


Fig.3.6. Variation of Carbon monoxide with CR

3.2.2. Hydrocarbon

It can be observed from the Fig.3.7 that HC emissions decrease with increase in CR for all the fuels tested which is due to complete combustion of fuel at higher CR. It is also observed that HC decreases with the increase in blend proportion. This is due to better combustion of Honne biodiesel due to its oxygenated nature. The mean percentage decrease in HC emission with Honne biodiesel as compared to Diesel is of the order of 58 %.

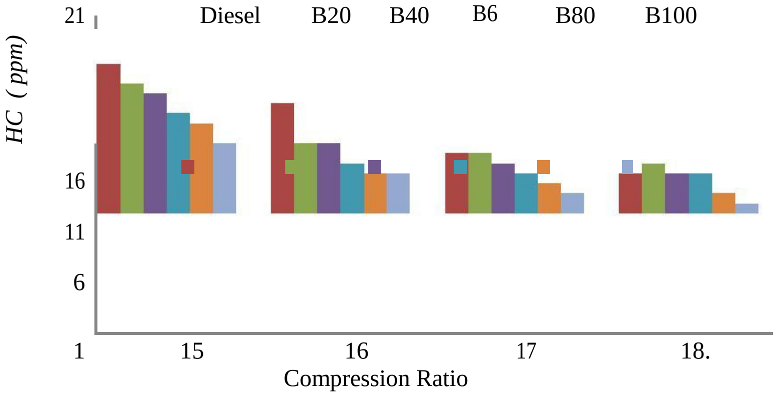


Fig.3.7. Variation of Hydrocarbon with CR

3.2.3. Nitrogen Oxides

It can be observed from the Fig.3.8 that as CR increases NOx emissions increases for blends while it decreases for Diesel. At a CR of 15 the NO_X emissions for Diesel are higher by 70.4% and at CR 18 they are lower by 24.6% as compared to Honne biodiesel. At higher CRs of 17 to 18 NOx emission is found to be higher for the blends as compared to that of Diesel.

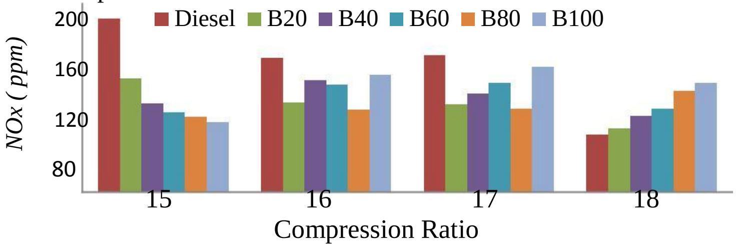


Fig.3.8. Variation of Nitrogen oxides with CR

3.2.4. Carbon Dioxide

It is observed from the Fig.3.9 that CO2 emission initially decrease, reach the lowest and subsequently increase with the increase in CR for all the fuels tested. CO2 emission is higher for biodiesel compared to Diesel at all CRs. It can be noted that the percentage decrease in CO_2 emissions between Honne Biodiesel and Diesel over the range of CRs is 22%.

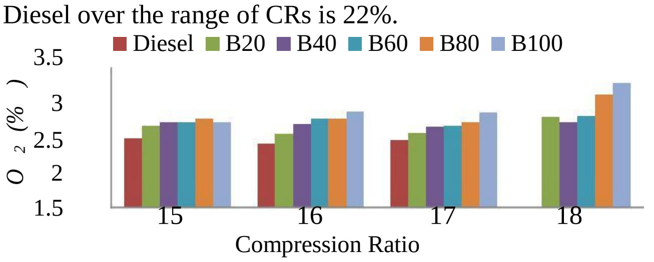


Fig.3.9. Variation of Carbon dioxide with CR

3.2.5. Smoke Intensity

Smoke intensity is measured in Hartridge Smoke Unit (HSU) and expressed in %. Higher HSU indicates that either excess fuel is burnt or the fuel burning process is not efficient. It is observed from the Fig.3.10 that smoke is less at higher CR for all the fuels. This may be due to complete combustion as the heat of the compressed air is high. At lower CR, smoke is high as incomplete combustion of fuel takes place. HSU is lowest for B40 blend compared to all other blends. As the CR increases from 15 to 18, HSU decreases by 45% for Diesel and 40% for pure Honne biodiesel. At a CR of 18, the HSU for pure Honne biodiesel is 2.4% more than that for Diesel.

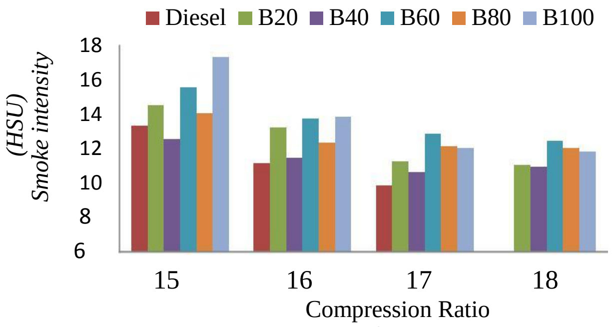


Fig.3.10. Variation of Smoke intensity with CR

IV. CONCLUSION

The change in CR does not have much effect on the HGas of the engine. However, at most of the CRs it is less for Honne biodiesel than Diesel. The performance study reveals that the blend B20 operates very close to Diesel with respect to thermal performance. However the performance of Honne biodiesel approaches that of Diesel fuel at higher CRs. Therefore it can be concluded that higher CR should be the mode of operation when engine is fuelled with Honne biodiesel.

At higher compression ratios (16 to 18), combustion of fuel is efficient due to high temperature of compressed air. Due to which, the exhaust emissions are found to reduce at higher CRs. Also at higher CRs, smoke is less due to complete combustion of fuel. However, the NOx emissions are found to increase at higher CRs with Honne biodiesel as compared to Diesel. There is need to trade off between NOx and smoke emission. So the selection of

CR can be based on the combined effect on thermal performance and emission characteristics. It is preferable to operate the engine at CR of 18 for optimum thermal performance. If NOx is considered then it is better to operate

at CR 16.But it causes decrease in BTE of about 13% and increase of BSFC of about 13% which are not recommendable just to reduce NOx emissions.

It is found that CO2 emissions are more for Honne biodiesel than that of diesel. Higher CO2 emissions reduce

harmful CO emissions. The percentage reduction in HC emissions for Honne biodiesel is about 60% as compared to that of Diesel. Due to higher NOx emissions with pure Honne biodiesel, suitable blends can

become a striking balance between NOx emissions on one end and all other emissions along with performance on the other hand.

The emission characteristics show that the Honne biodiesel gives minimum harmful emissions as compared to all other blends. Further, at a higher CR of 18 the fairly reduced exhaust emissions are observed irrespective of the fuel. Therefore, in operating the diesel engine with Honne biodiesel at a CR of 18 results in minimum emissions but more NOx emissions.

V. REFERENCES

[1] Torres EA, Cerqueira G S, Ferrer TM, Quintella C M,Raboni M,Torretta V, Giordano Urbinic. Recovery of different waste vegetable oils for biodiesel production: a pilot experience in Bahia State, Brazil. Waste management; vol. 33, p. 2670-2674, 2013.

[2] Chavan SB, Kumbhar RR, Deshmukh RB, Callophyllum Inophyllum Linn (“honne”) Oil: A source for Biodiesel Production. Research Journal of Chemical Sciences; Vol. 3(11), p.24-31, November 2013.

[3] Sanjaykumar Dalvi, Swati Sonawane, Raghunath Pokharkar, Preparation of Biodiesel of Undi seed with In-situ Transesterification. Leonardo Electronic Journal of Practices and Technologies;ISSN 1583-1078,Issue 20, pp. 175-182, January-June 2012.

[4]Onga HC, Mahlia TMI, Masjukia HH, RS Norhasyimab. Comparison of palm oil, Jatropha curcas and Calophyllum inophyllum for Biodiesel. Renewable and Sustainable Energy Reviews; vol.15, p.3501–3515, 2011.

[5] Vasanthakumar SS, Dinesh KS, Jalagandeeswaran K, Premkumar MP, Sivanesan S, Two-step biodiesel production from Calophyllum inophyllum oil: Optimization of modified b-zeolite catalyzed pre-treatment.Bioresource Technology;vol.102, p.1066–1072, 2011.

[6] Venkanna BK, Venkataramana Reddy C. Performance, emission and combustion characteristics of direct injection diesel engine running on calophyllum inophyllum linn oil (honne oil). Int J Agric & Biol Eng, 2011,vol. 4(1).

[7] Sivaramakrishnan Kaliamoorthy, Ravikumar Paramasivam. Investigation on performance and emissions of a biodiesel engine through optimization techniques. Thermal Science; Year 2013, Vol. 17, No. 1, pp. 179-193.

[8] Shelke RE. Feasibility Study of Soyabean Oil as an Alternate Fuel for CI Engine at Variable Compression Ratio. International Journal of Chemical and Physical Sciences; Vol. 2, No. 4, July-Aug 2013, ISSN:2319-6602.

[9] Mohammed EL_Kassaby, Medhat A Nemit_allah. Studying the effect of compression ratio on an engine fueled with waste oil produced biodiesel/diesel fuel. Alexandria Engineering Journal;Volume 52, Issue 1, March 2013, P.1–11.

[10] Sejal Narendra Patel, Ravindra Kirar. An Experimental Analysis of Diesel Engine Using Biofuel at Varying Compression Ratio. International Journal of Emerging Technology and Advanced Engineering; Volume 2, Issue 10, October 2012 , ISSN 2250-2459.

[11] M. K. Duraisamy, T. Balusamy , T. Senthilkumar. Effect of Compression Ratio on CI Engine Fueled With Methyl Ester of Thevetia Peruviana Seed Oil. ARPN Journal of Engineering and Applied Sciences; Vol. 7, No. 2, February 2012, ISSN 1819-6608.

[12] R. Anand, G.R. Kannan, K. Rajasekhar Reddy, S. Velmathi. The performance and emissions of a variable compression ratio diesel engine fuelled with bio-diesel from cotton seed oil. ARPN Journal of Engineering and Applied Sciences; Vol 4, p. 72-86, 2009.

[13] Magin Lapuerta, Octavio Armas, Jose Rodriguez Fernandez. Effect of biodiesel fuels on diesel engine emissions. Progress in Energy and Combustion Science; vol. 34,2008, pp 198–223.