ChemTech

International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.9, No.09 pp 508-513, 2016

Performance and Emission Characteristics of a Diesel Engine using Blends of Biodiesel by varying Saturated Fatty acid Compositions

P.Tamilselvan[1]*, G. Nagarajan[2], and M.Sasikumar[1]

[1]School of Mechanical and Building Sciences, VIT- Chennai Campus, Chennai-600048, Tamil Nadu, India
[2]Department of Mechanical Engineering, I.C. Engineering Division, Anna University, Chennai-600025, Tamil Nadu, India

Abstract : This work discusses about blends of vegetable oil esters with varying saturated fatty acid composition which were used to conduct the performance and emission tests on a stationary C.I.Engine. Saturated fatty acids are long-chain carboxylic acids that usually have between 8 and 24 carbon atoms and have no double bonds. The unsaturated fatty acids are similar to saturated fatty acids, excluding that the chain has double bonds. Biodiesels were made from pongamia, palm, coconut, mahua, neem, cottonseed and Jatropha with saturated fatty acid composition as 55%, 65% and 75% respectively. The biodiesels has lauric acid, myristic acid, palmitic acid, linoleic acid, linolenic acid, stearic acid and oleic acid in varying proportions. The experimental results support that biodiesel having high-saturated fatty acid composition can be used as a fuel in a CI engine without compromising on thermal efficiency. The NOx and hydrocarbon emission reduces with increase in saturation percentage in biodiesel while smoke emissions are increased. Biodiesels with high saturated fatty acid composition has higher cetane number, density and viscosity. Ignition delay and NOx emissions reduces with increase in cetane number.
Keywords: Saturated fatty acid, cetane number, thermal efficiency, combustion, ignition delay.

1. Introduction

Diesel fuel is a mixture of hydrocarbon (HC) molecules of differing lengths and structures, whereas vegetable oils are generally composed of triglycerides whose molecular structures are branched and complex. The presence of oxygen molecules in vegetable oils improves the combustion efficiency when compared to that of diesel. Vegetable oils have lower calorific value and higher cetane number when compared to diesel. The problems encountered during engine tests with vegetable oils are carbon deposits on fuel injector, piston and rings, gum formation and crankcase polymerization. In order to reduce the viscosity of vegetable oils, which is the main cause for gum formation, Conversion of vegetable oil to methyl and ethyl esters is called as bio-diesel and it is one technique to overcome the problems associated with vegetable oils, like crankcase polymerization. Biodiesel contains many fatty acids. Fatty acids that contain carbon-carbon double bonds are known as unsaturated fatty acid. Fatty acids without double bonds are known as saturated fatty acids. Pairs of carbon atoms connected by double bonds can be saturated by adding hydrogen atoms to them, converting the double bonds to single bonds. Therefore, the double bonds are called unsaturated. Saturated fatty acids usually have 12 to 24 carbon atoms and have no double bonds.

The earlier studies by researchers reveal that usage of biodiesel as fuel in diesel engines were heavily influenced by their physical and chemical properties. Literatures show that bio diesel was produced by the transesterification of vegetable oil by using suitable catalyst like sodium hydroxide and potassium hydroxide[1, 2, 3, 4, 5, 6]. Schmidt et al reported that high oxygen content improves combustion efficiency and reduces hydrocarbon and smoke emissions and oxygen availability is attributed to the formation of NO[7]. Tat et al[8] reported that bulk modulus can be taken as a measure of compressibility resistance. Bulk modulus decrease with increase in temperature and increase with increase in pressure. The compressibility of vegetable oil esters are less when compared to diesel. This less compressibility leads to increased mass delivery of the fuel. Tottel et al [9] observed that fuels with high cetane number increase the power output, better cold start properties and reduce smoke emissions. A study by Knoth et al [10] show that the cetane number of the fuel increases with saturated fatty acid in biodiesel. The presence of double bond reduces the chain length in unsaturated fatty acids while the absence of double bond increases the chain length in saturated fatty acid. Usta et al [11] observed that biodiesels have higher viscosity compared to high speed diesel oil. The biodiesel viscosity affects the fuel injection characteristics and fuel atomization. The higher viscosity leads to increase in biodiesel fuel injection by mass. The use of biodiesel in diesel engines influences the performance and emissions of the engine. Deepak Agarwal[12] conducted experiments with jatropha biodiesel and found brake thermal efficiency increase and smoke emission decrease for 200 bar nozzle opening pressure. However further increase in nozzle opening pressure from 200 to 240 bar reduced the brake thermal efficiency and increased the smoke emissions. Anand et al [13] reported that a maximum of 2.3degree CA (crank angle) advance in dynamic fuel injection timing was observed with biodiesel compared with the diesel fuel. Murat karabektas [14] studied the effects of a turbocharger on a diesel engine with biodiesel as fuel. It was reported that BSFC increase was mainly due to lesser calorific value and higher density of biodiesel. Nabi et al[15] carried out tests with biodiesel produced from cottonseed oil (CSO). The engine experimental results showed reduction in carbon monoxide and smoke emissions whereas a marginal increase in oxides of nitrogen (NOx) emission. Ameya vilas Malvade et al [16] investigated the effects of using palm oil ester in a stationary single cylinder diesel engine. The properties of palm oil ester were comparable with that of diesel. The results of the performance tests showed that the brake thermal efficiency was comparable with diesel. The biodiesel prepared from fats from goat and sheep produced lesser oxides of nitrogen emission[17]. From the literatures, it was observed that when biodiesels are used as fuels in diesel engines they produce higher emission of NOX, and lesser emission of hydrocarbon and smoke[18]. The brake thermal efficiency with biodiesel operation is comparable to conventional diesel. Hence the objective of the present work is to focus on studying the effect of saturated fuel composition in biodiesel with different blends in a diesel engine.

2. Experimental methods

A single cylinder, water cooled, four stroke, Compression Ignition Engine capable of developing 5.2 kW at 1500rpm was chosen for conducting the experiments. The engine specifications are shown in Table1. An eddy current dynamometer coupled to the engine was used as a loading device. The exhaust gas temperature was measured by a K-type thermocouple in conjunction with a digital temperature indicator. AVL Di Gas444 gas analyzer was used to measure the exhaust emissions from the engine. The smoke intensity was measured by Bosch smoke meter. In addition, filter paper of diameter 50 mm was used to collect smoke samples from the engine, through a smoke sampling pump for measuring the Bosch smoke number. Cylinder pressure was measured by a water cooled piezoelectric transducer of range zero to 250 bar. The properties like density, viscosity, heating value, cetane number, iodine value, saponification value and moisture content were measured in ITALAB Pvt. Ltd, Industrial Testing and Analytical Laboratories (An ISO 9001: 2000 Certified organization), Chennai, India. Table 2 gives the properties of the vegetable oil esters used for the experiments.

Table1: Engine Specifications

Parameter	Specification
Model	Kirloskar TAF-1
Type	Single cylinder, four stroke, direct injection
Capacity	661 cm^3
Bore and stroke	87.5mm×110 mm
Compression ratio	17.5:1
Speed (constant)	1500 rpm
Rated power	5.2KW
Cooling system	Water cooling
Injected timing	23 ˚b TDC
Fuel injection pressure	200 bar

Table2: Properties of Vegetable oil Esters

S.No	Properties	55% Saturation	65% Saturation	75% Saturation
1	Density	881.1	874.2	861.1
2	Kinematic viscosity	5.35	5.25	4.77
3	Cetane Number	54	55.5	59
4	Heating value	39.9	40.1	39.4
5	Iodine value	65.4	55.6	31.4
6	Saponification value	201.6	211.8	230.9

Biodiesel fuels with 55% and 65% saturation levels having pongamia oil methyl esters and coconut oil esters have lesser density when compared to fuels with palm oil methyl blends. Increase in saturation levels of fuels reduces the viscosity. The high viscosity of fuel affects the fuel injection characteristics and fuel atomization. The cetane number varies from 52 to 56 for fuels with 55% saturation level and 53 to 57 for fuels with 65% saturation levels. Higher cetane numbers are observed for fuels with 75% saturation levels and it varies from 57 to 61. The average heating values of biodiesel with pongamia oil methyl esters (38.5 MJ/kg) are lesser than coconut oil (39.5 MJ/kg) and palm oil based (40.3 MJ/kg) biodiesel fuels. The iodine value reduces with increase in saturation and is lesser for fuels with 75% saturation level. The increase in iodine value for palm oil methyl esters is due to the presence of double bonds in oleic and linoleic acid. The molecular weight of fatty acids and the chain length of fuel is inversely proportional to saponification value. The saponification values is higher for 75% saturation fuels.

3. Results and Discussion

The brake thermal efficiency for biodiesels with different saturation levels is shown in Figure 1. The average values of brake thermal efficiency of fuels with 55%, 65% and 75% are 27.2%, 28.1% and 28.9% respectively. The higher efficiency may be attributed to the higher cetane number which gives improved combustion efficiency. Figure 2 shows the oxides of nitrogen emission for biodiesels with different saturation levels. The average values of oxides of nitrogen emissions of fuels with 55%, 65% and 75% are 12.7, 12.1 and 11.7 g/kWh respectively. The reduction in oxides of nitrogen emission is mainly due to higher cetane number and lesser iodine value. The hydrocarbon emission for biodiesels with different saturation levels is shown in Figure 3. The average values of hydrocarbon emissions of fuels with 55%, 65% and 75% are 0.32, 0.31 and 0.29g/kWh respectively. The reduction in hydrocarbon emissions for fuels with higher saturation levels may be due to higher cetane number which improves combustion inside the engine. The carbon monoxide emission for biodiesels with different saturation levels is shown in Figure 4. The average values of hydrocarbon emissions of fuels with 55%, 65% and 75% are 2.1, 1.8 and 1.7 g/kWh respectively. The increase in carbon monoxide emissions for fuels with lower saturation levels may be due to higher density and viscosity of fuels which affects the fuel combustion. The variation of smoke for biodiesels with saturation levels is shown in Figure 5.The smoke increases marginally with increase in saturation levels. The marginal increase in smoke emission is due to the presence of more hydrogen atoms for fuels with higher saturation levels and the affinity of oxygen towards hydrogen leaving less oxygen to react with carbon.

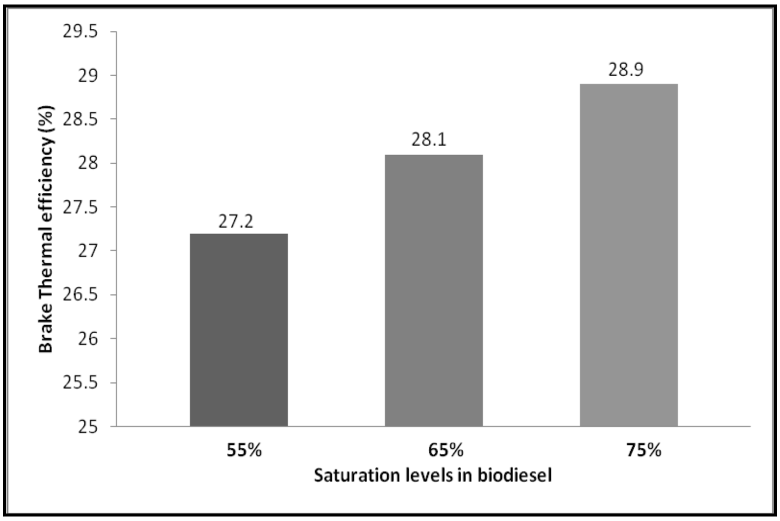

Fig:1 Variation of Brake Thermal Efficiency for different biodiesels

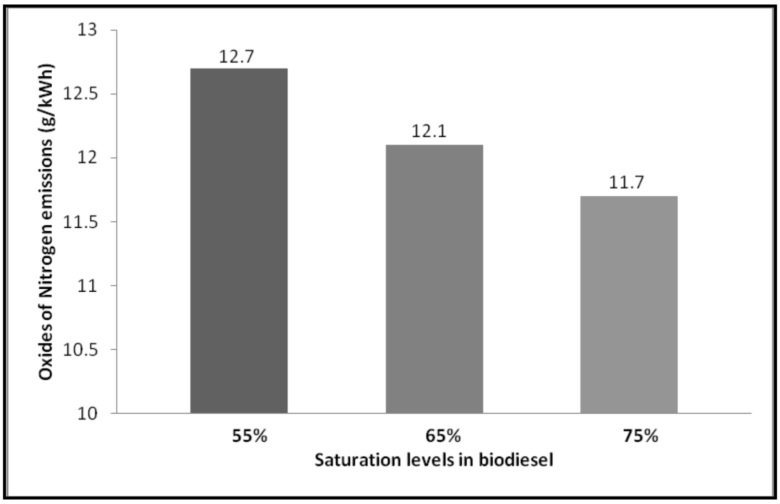

Fig:2 Variation of Oxides of Nitrogen Emission for different biodiesels

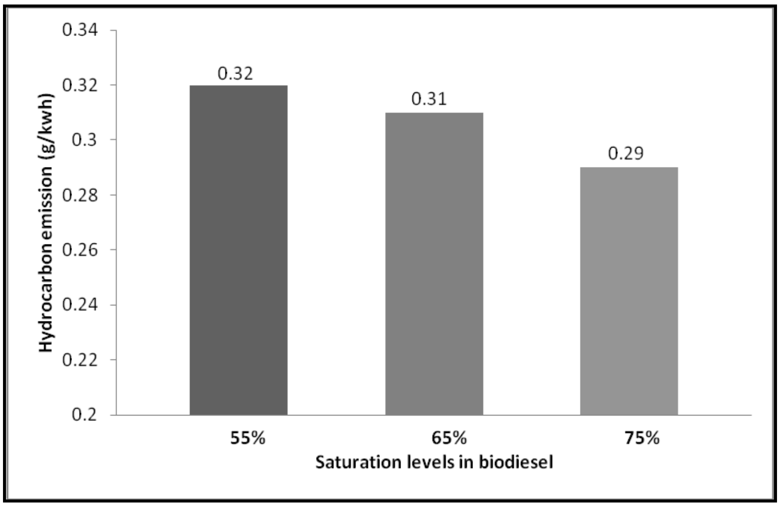

Fig:3 Variation of Hydro carbon Emission for different biodiesels

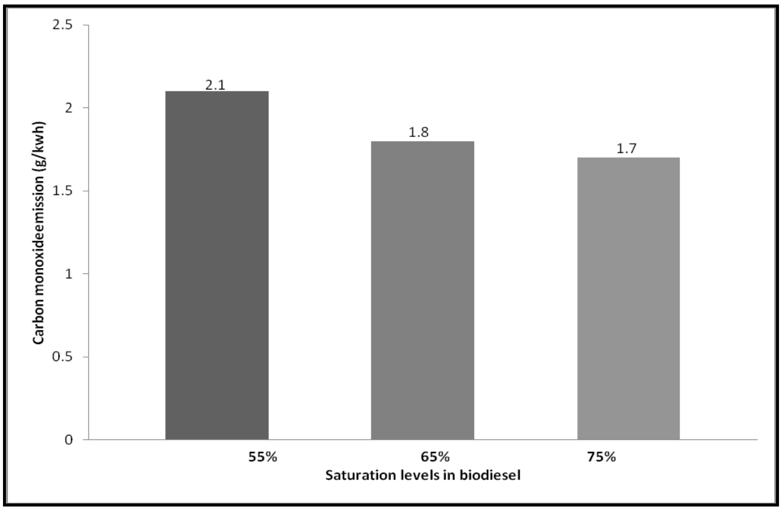

Fig:4 Variation of Carbon mono oxide Emission for different biodiesels

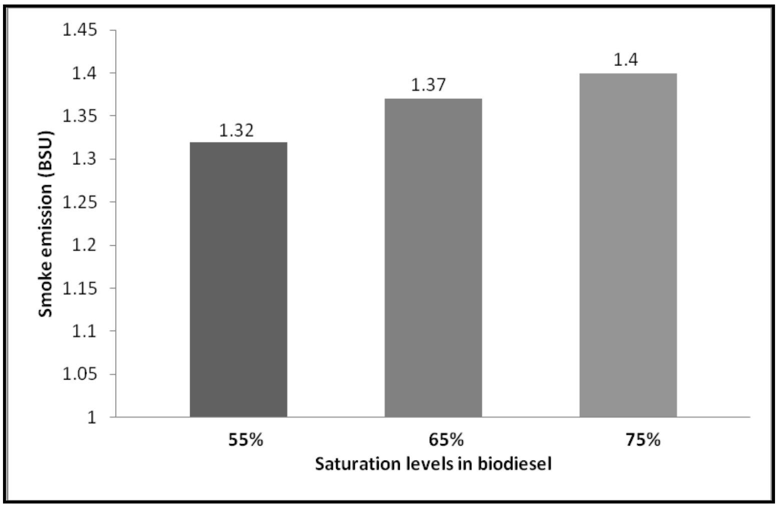

Fig:5 Variation of Smoke Emission for different biodiesels

4. Conclusion

An increase of 15% in saturated fatty acid resulted in thermal efficiency increased by about 3% and NOx emissions reduced by about 5%. Among all the fuels, esters with 75% saturated fatty acid composition which are mainly derived from coconut oil emitted lesser NOx emissions. This may be due to the presence of saturated fatty acids like lauric acid (C12:0), myristic acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0) in their composition. Fuels with high saturated fatty acids have higher cetane number. High cetane number reduces the ignition delay, pressure and temperature which reduce NOx emissions. The experimental results show that biodiesel with high-saturated fatty acid composition can be easily used as a fuel in a CI engine

References:

1. Rajagopal K, Jhonson J and Selwin Rajadurai J, Production of biodiesel from waste used cooking oil using two different alkaline catalysts, International Journal of Chemtech Research, 2015, 8(2), 754-759.
2. Adhikesavan C, Rajagopal K and Selwin Rajadurai J, Production and characterization of biodiesel from Acacia nilotica seeds, International Journal of Chemtech Research, 2015, 8(2), 854-859.
3. Jimmy and Christian Andrew, Microwave assisted to biodiesel production from palm oil in time and material feeding frequency, International Journal of Chemtech Research, 2015, 8(4), 1695-1700.
4. Syed Aalam C and Saravanan CG, Biodiesel production from Mahua oil via Catalytic transesterification Method, International Journal of Chemtech Research, 2015, 8(4), 1706-1709.

5. Prema D, Lakshmi Prabha M and Gnanavel G. Production of biofuel using waste papers from pseudomonas aeruginosa, International Journal of Chemtech Research, 2015, 8(4), 1803-1809.
6. Muthu, K & Viruthagiri, T. Application of solid base calcium oxide as a heterogeneous catalyst for the production of biodiesel, International Journal of Chemtech Research, 2015, 8(4), 2002-2008.
7. Schmidt K. and Van Gerpen J.,The effect of biodiesel fuel composition on diesel combustion and emissions, SAE Technical Paper, No. 961086,1996.
8. Tat E., Van Gerpen H., Soylu S., Canakci M., Monyem A. and Wormley S., The speed of sound and isentropic bulk modulus of biodiesel at 21^{o}C from atmospheric pressure to 35 MPa, Journal of American Oil and Chemical Society, 2000, 77, 285–289.
9. Tottel G., Fuels and lubricants handbook: technology, properties, performance, and testing, ASTM International, USA, Chapter- 4, 2000.
10. Knothe G., Matheaus A. and Ryan T., Cetane numbers of branched and straight-chain fatty esters determined in an ignition quality tester, Fuel, 2003,82,971–975.
11. Usta N., An experimental study on performance and exhaust emissions of a diesel engine fuelled with tobacco seed oil methyl ester, Energy Conversion & Management, 2005, 46, 2373–86.
12. Deepak Agarwal, and Avinash Kumar Agarwal, Performance and emissions Characteristics of Jatropha oil (preheated and blends) in a direct injection compression ignition engine, Applied Thermal Engineering, 2007, 27, 2314-2323.
13. Anand K., Sharma R.P. and Mehta P.S., Experimental investigations on combustion, performance, and emissions characteristics of a neat biodiesel – fuelled, turbocharged, direct injection diesel engine, Journal of Automobile Engineering, 2009,224,661-79.
14. Murat Karabektas,The Effects of turbochargers on the performance and exhaust Emissions of a diesel engine fuelled with biodiesel, Renewable Energy, 2009,34,989-993.
15. Nabi M.N., Md. Mustafizur Rahman, and Md. Shamim Akhter, Biodiesel from cotton seed oil and its effect on engine performance and exhaust emissions, Applied Thermal Engineering, 2009, 29(11-12),2265–2270.
16. Ameya Vilas Malvade, Sanjay Satpute T., Production of palm fatty acid distillate biodiesel and effects of its blends on performance of single cylinder diesel engine, Procedia Engineering , 2013, 64, 1485-1494.
17. James Selvakumar M, John Alexis S and Sundarraj K, Emission characteristics of a CI engine with the addition of different additives, International Journal of Chemtech research, 2015, 8 (4), 2064-2071.
18. Mohanamurugan S., & Sendilvelan S., Emission and combustion characteristics of different fuel In A HCCI engine. International Journal of Automotive and Mechanical Engineering, 2011,3, 279-92.

*****