Experimental Investigation of Performance and Emission of Diesel Engine Fuelled with Preheated Jatropha Biodiesel and its Blends with Ethanol

Shiyasharan Patel*, Dr. Nitin Shrivastava

*Department of Mechanical Engineering, University Institute of Technology,Rajiv Gandhi Proudyogiki Vishwavidyalaya Bhopal, India

‡Corresponding author mail address: mesiyasharan@gmail.com

Received: 10.07.2016 Accepted:16.08.2016

Abstract- As the cost of petroleum fuel is rising day by day. Here is a rising demand for research for sustainable atmosphere and cost effective alternate fuel. Conventional fuel like diesel is replaced with alternative fuels as these fuels are economically, attractive and renewable. Bio-diesel fuel is diesel fuel replacement, and has a few attractive properties such as biodegradability, renewability, comparable performance as well as low emission. The bio-diesel viscosity is higher than diesel fuel. The current investigation is to reduce the bio-diesel viscosity by pre-heating. In this experimental analysis diesel fuel, Jatropha bio-diesel, preheated Jatropha bio-diesel (PJBD), 80% preheated Jatropha bio-diesel-20% ethanol (PJBD80E20) fuels is tested. Experiment has been performed on the basis of constant revolution per minute, and the engine is taken as diesel engine tested on different loading conditions. The experimental analysis is based on the performance parameters like brake specific fuel consumption, brake thermal efficiency along with the exhaust emission parameters like CO, HC, NOx and smoke. This research paper is based on the comparison of different fuels with respect to the diesel which is taken as reference fuel. Eventually it is concluded that BTE decreases slightly whereas BSFC increases as the engine fuelled with PJBD80E20 as compare to neat diesel fuel at different load conditions. In the same testing condition, a slight decrease in CO and HC emission and significant reduction in NOx emission were observed, however, there is a slight increase in smoke emission was observed as compare to diesel fuel.

Keywords - Preheated biodiesel, ethanol blending, performance analysis, Engine emission, jatropha biodiesel.

Abbreviation

BSFC:	Brake Specific Fuel Consumption
BTE:	Brake Thermal Efficiency
CO:	Carbon monoxide
HC:	Hydro-Carbon
NOx:	Nitrogen Oxides
JBD:	Jatropha Bio-diesel
PJBD:	Pre-heated Jatropha Bio-diesel
PJBD80E20:	80% Pre-heated Jatropha Bio-diesel 20%Ethanol
CV:	Calorific Value

1. Introduction

The economy and Industrial growth of every country depend on its energy resources. Petroleum energy resources are one of those energy resources. India recognized as the fastest rising economy with consumption of the 872 Million -Ton oil equivalent of energy, which is the third-largest in the world [1]. The demand for energy is very high due to the rapid increase in population and gross domestic production. Migration from rural to an urban area is the main reason of changing in utilization pattern and builds contribution in rising energy demand. The present world has been modernized and industrialized, where the petroleum fuel resources have become necessary for automobiles and other purposes. Hence, there is rapid consumption of petroleum resources, which are very inadequate in quantity. The rate of fuel pricing, is rising continuously for meeting the supply, the growing demand of petroleum intensifies air pollution as well as magnifies the ecological trouble such as, carbon mono -oxide, hydro-carbon, smoke, nitrogen oxides emissions, etc. So there is a need to discover new options and alternatives, which are easily available, abundant in nature and renewable. This is not a new idea that vegetable oils used in diesel engines. In the past few decade vegetables, oils have emerged as an alternative fuel. Vegetable oils have similar properties to that of fossil fuels such as physical composition and combustion characteristics. The interesting thing about the vegetable oils is their renewable and eco-friendly behavior as well as the fact that they are obtained from different plants and seeds, which can be easily cultivated in our rural areas. Vegetable oils can either be non-edible or edible. Examples of Few of the edible oils are soya oil, peanut oil and cottonseed oil. The edible oils are mahua oil, Jatropha oil, Karanja oil, rubber seed oil, neem oil, etc. The vegetable oils are used on a diesel engine with no modification results in the wear and lack the effective performance of the engine parts [2]. These problems are recognized to high viscosity as well as low volatility character of vegetable oils, various run time difficulties such as fuel nozzle chocking as well as the piston ring sticking [3-4]. Methods to decrease the high viscosity as well as an increase the volatility of vegetable oils such as preheating, transesterification, blending and micro-emulsification, etc. [5]. The transesterification is a process to diminish the high viscosity by chemical transform of triglyceride's particle into the methyl esters of vegetable oil. These methyl esters are capable replacement fuels for the compression ignition engine and are called bio-diesel. Bio-diesel fuel has attractive properties such as renewability, biodegradability, comparable performance, nontoxic, low emission and pure burning diesel replacement. Several researchers have found the similar performance parameters of the direct-injection combustion fuelled with bio-diesel of different feed stocks [6-13]. The various researchers illustrate the similar of the four stroke direct injection single cylinder diesel engines fuelled with Jatropha biodiesel conventional diesel fuel. It was found that performance like BTE is approximately same and exhaust emissions of CO, HC as well as smokes was decreased, but NOx emission was increased than the conventional diesel fuel [14-17]. From the result obtained it can be concluded that viscosity of Jatropha bio-diesel results in low combustion and slightly lower thermal efficiency and there is a need to develop a mechanism to reduce the viscosity of Jatropha bio-diesel to improve its performance characteristics. It is well known that the viscosity diminishes with augment in temperature. The blend PJBD80E20 enhances the atomization and decreases the viscosity as well as blending procedure, which results in improved ignition. In the current study tested Jatropha bio-diesel was preheated and blended with ethanol, and tested in the diesel engine at different loading conditions. The results of different parameters were compared to the baseline diesel fuel.

2. Experimental Setup and Methodology

The experimental setup consists of a single cylinder, four strokes, water Cooled, the diesel engine and an engine investigation with a rope brake dynamometer. The engine was attached to a rope brake dynamometer, and the engine was run at a constant revolution per minute. The experimental analysis is based on the performance parameters as well as the investigation of the exhaust emission at different loads. The performance parameter includes BTE and BSFC. The exhaust gas analyzer was used to found emissions like carbon monoxide, nitrogen oxides, hydro-carbon, etc., and a smoke meter was used to measure smoke emissions. These performance parameters as well as exhaust emissions for Jatropha bio-diesel, pre-heated Jatropha bio-diesel, PJBD80E20 is compared to the result of neat diesel fuel. The technical specification of the test engine as shown in figure 1 is given in the table 1.

Table 1: Specification of test engine

Engine Parameters Details	**Details**
Make	Kirloskar Oil Engine, Pune
Model	SV1
Type	Four Stroke diesel Engine, WaterCooled
No. Of Cylinder:	One
Bore Size	87.5 mm

Stroke Length	110 mm
Cubic Capacity	662 CC
Compression Ratio	16.5:1
Engine RPM	1500
Rate of Output	5.88kW / 8 HP

Figure 1: Experimental Setup

3. Results and Discussion

3.1. Properties of Fuels

The different fuel properties of diesel fuel, ethanol, JBD are compared and given in the table 2.

Table 2: Contrast of the Physical properties of Diesel fuel, ethanol, JBD

Property	**Diesel fuel**	**Ethanol**	**Jatropha biodiesel**
Density at 40^0 C (kg/m^3)	822.4	790	893.2
Specific Gravity	0.8224	0.79	0.8932
Kinematic Viscosity at 40^0C (cst)	2.4	1.2	5.8
Cloud Point	3.1	5.4	3.5
Pour Point	6.5	-118	-12
Flash Point	67	13	167
Lower CV (kJ/kg)	42.7	26.80	38.92

3.2. Brake Specific fuel Consumption

The most essential performance parameter of different fuel is BSFC. The BSFC for diesel fuel, JBD, PJBD, PJBD80E20 is depicted in figure 2. With the increase of engine loads the lower BSFC were observed. The Jatropha bio- diesel has higher viscosity and lesser calorific value, so it's BSFC is higher to that of conventional diesel fuel. The Jatropha bio-diesel also has the slight difficulty in atomization [18]. The BSFC of PJBD is higher to that of conventional diesel fuel and lesser as compared to Jatropha bio-diesel, because of lower viscosity of Jatropha bio-diesel to enhance combustion and atomization [19]. If the engine is fuelled with PJBD80E20, BSFC increases slightly as compared to PJBD and decreases as compared to JBD due to lesser calorific value of ethanol.

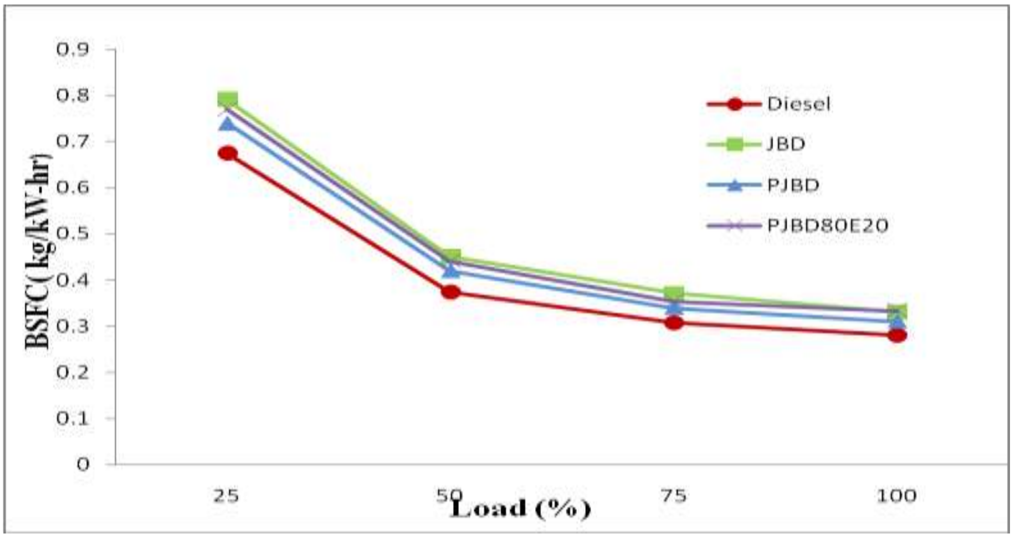

Figure 2: Brake Specific fuel Consumption with loads

3.3. Brake Thermal Efficiency

The BTE for diesel fuel, JBD, PJBD, PJBD80E20 is depicted in figure 3. The BTE increases as the engine load increases for all the tested fuels. The BTE of JBD was lowered than the diesel fuel at various engine loads. This may be due to the lesser calorific value as well as the higher viscosity of JBD fuel. The BTE for preheated Jatropha biodiesel is higher than the Jatropha biodiesel because of the preheating process helps to decrease viscosity of the fuel and improve the fuel atomization[20]. The better atomized fuel represents the smaller fuel particle diameter which leads to improved combustion efficiency. It was seen that ethanol blended preheated Jatropha biodiesel fuel results in higher brake thermal efficiency than the Jatropha biodiesel and less than the preheated Jatropha biodiesel at various engine loads. The possible reason of reduced BTE of PJBD80E20 than PJBD is ethanol which has lower calorific value.

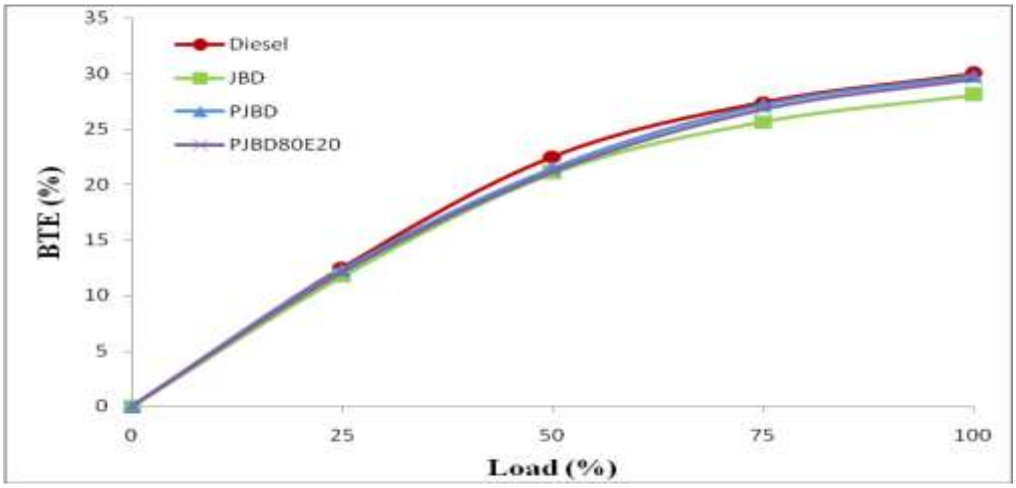

Figure 3: BTE with loads

3.4. CO Emission

The formation of carbon monoxide emission mostly depends upon the physical and chemical properties of the fuel used. The CO emission of diesel fuel, JBD, PJBD, preheated Jatropha biodiesel and its mixture with 20% ethanol is shown in figure 4. The CO emission increases when engines load increases. The JBD is lesser CO emitters than diesel fuel because of oxygen present in JBD. Its combustion is also better. The carbon monoxide emission of preheated Jatropha biodiesel is less than all tested fuel. This is because of preheated JBD reduces the viscosity, which improves the combustion of fuel. The CO emission of mixture PJBD80E20 is more than JBD and PJBD but found lower than diesel fuels at various engine loads. The increased CO emission of PJBD80E20 as compared to PJBD may be attributed to reduced delay period of fuel as ethanol fuel has lower cetane number.

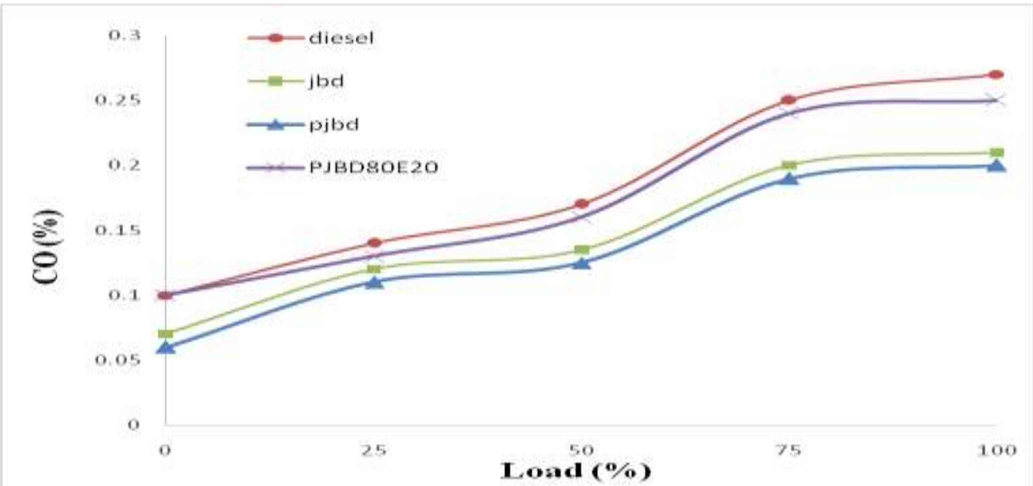

Figure 4: Carbon monoxide emission with loads

3.5. HC Emission

These are hydrocarbon particles present in exhaust gases that went out of a combustion chamber. While hydrocarbon emission gets into an environment, these acts as irritants odorants, a few are carcinogenic. As shown in figure 5, the hydrocarbon (HC) emissions for diesel fuel, Jatropha bio-diesel, preheated Jatropha bio-diesel, and preheated Jatropha bio-diesel with 20% ethanol increases with the increase in engine loads. The JBD produces fewer hydrocarbons than neat diesel fuel because JBD has more oxygen content, which decreases hydro-carbon particles. The HC emission of PJBD diminished than JBD and neat diesel fuel. The HC emissions of PJBD80E20 were less as compared to neat diesel fuel but were higher than other two tested fuels at various engine loads. The higher HC emissions of PJBD80E20 may be due to poor ignitability of ethanol present resulted in inferior oxidation of fuel.

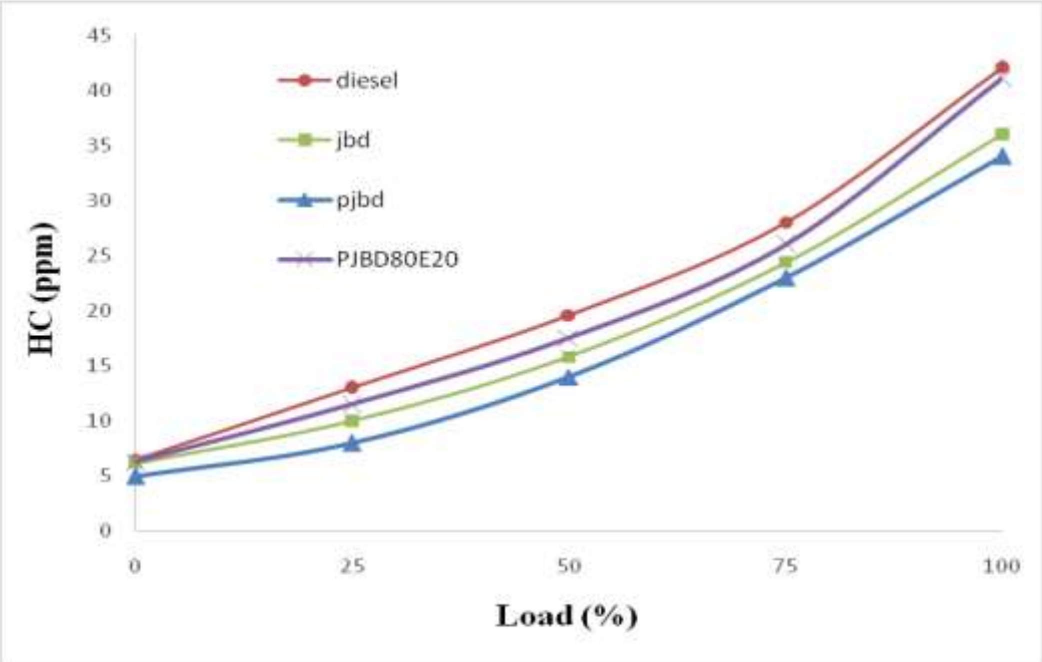

Figure 5: Hydrocarbon (HC) emission with loads

3.6. NOx Emission

Figure 6 illustrated the nitrogen oxide (NOx) emissions for diesel fuel, Jatropha bio-diesel, preheated Jatropha bio-diesel and preheated Jatropha bio-diesel with 20% ethanol. It was found that as the engine loads increase nitrogen oxides also increases. Nitrogen oxides formation in compression ignition engines is generally restricted by fuel cetane number and injection timing [21, 22], the blend stoichiometry at flame lift-off length in diesel sprays [23] and combustion pattern [24, 25].Which all associated to the chemical as well as physical properties of various feedstock and fuel injection systems [26].The JBD produces more nitrogen oxides than neat diesel fuel. The increase in NOx pattern can be recognized to higher oxygen molecules of Jatropha bio-diesel resulting in enhanced combustion temperature. The preheated Jatropha bio-diesel emits higher NOx than that of Jatropha bio-diesel. The nitrogen oxides emission increases because of their augmented fuel inlet temperature and improved fuel combustion [27]. The diesel engines when fuelled with PJBD80E20 showed the slight lesser NOx emission as compared to neat diesel fuel at various engine loads. The low calorific value of ethanol as well as high latent heat of evaporation resulted in reduced cylinder temperature and so NOx emission reduces.

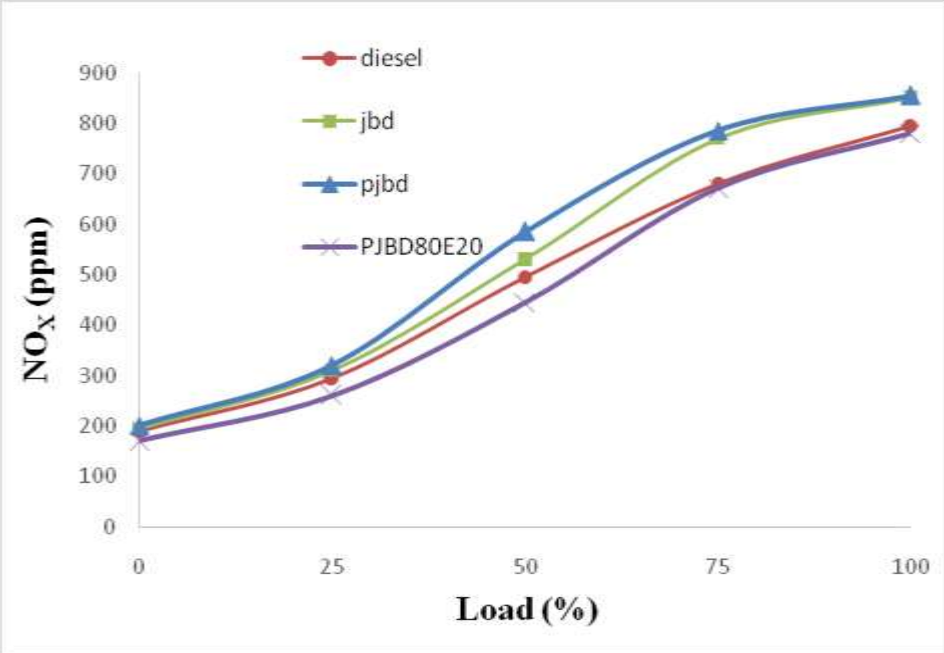

Figure 6: Nitrogen oxides emission with loads

3.7. Smoke Emission

Figure 7 shows the smoke emissions for diesel fuel, Jatropha bio-diesel, preheated Jatropha bio-diesel, and preheated Jatropha bio-diesel with 20% ethanol. The increase in engine loads increases the smoke emissions. The oxygen molecules present in the JBD increases the burning of fuel so JBD produces less smoke than neat diesel fuel. The PJBD produced lowered smokes emission than JBD as well as diesel fuels because of the increased fuel temperature. This led to increase the pre-flame reactions as well as diminishes the ignition delay [19]. The diesel engine when fuelled with PJBD80E20 showed the raise in smoke emission as compare to neat diesel fuel at different engine loads. The use of low cetane number blended ethanol leads to improper combustion may responsible for increased smoke emissions.

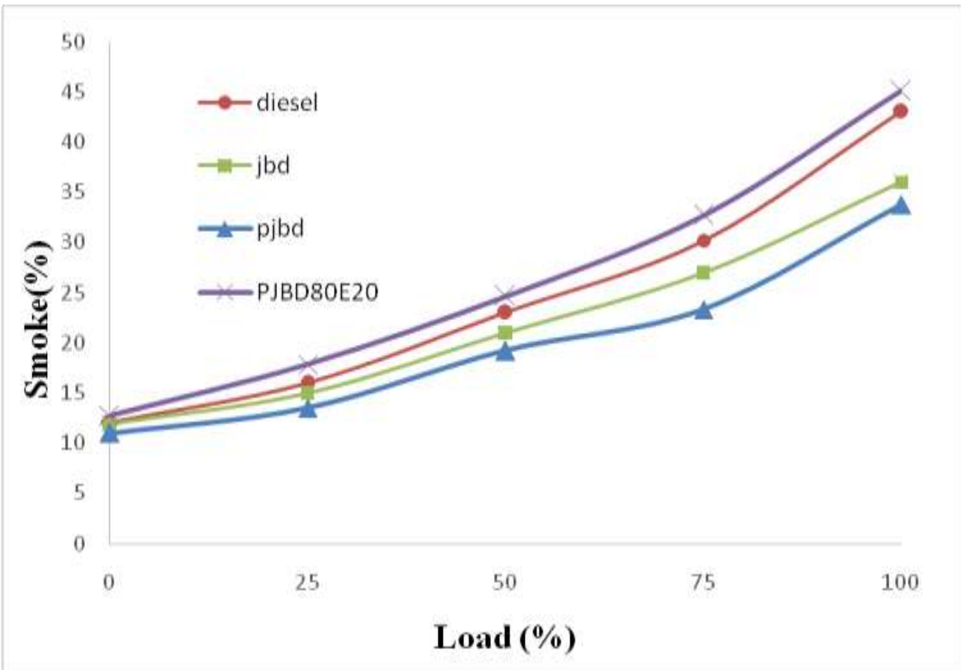

Figure 7: Smoke emission with loads

4. Conclusion

In this study, experiments are performed on the diesel engine fuelled with PJBD80E20 and results are compared with diesel fuel, Jatropha biodiesel and preheated Jatropha biodiesel. The following points are summarized based on the investigation of performance and exhaust emission parameters.

- BSFC was found maximum for Jatropha biodiesel and minimum for diesel fuel. Preheating of JBD reduces the BSFC, Whereas PJBD80E20 showed slightly higher BSFC than PJBD but lower than JBD.
- The BTE reduces slightly with the engine fuelled with preheated Jatropha biodiesel blended with ethanol as compare to neat diesel fuel because of their lesser calorific value of ethanol.
- The diesel engine when fuelled with PJBD80E20 showed the significant reduction in NOx emission compared to all tested fuels, CO and HC emission were lower than diesel but higher than JBD and PJBD.
- PJBD80E20 showed slightly higher smoke emission than all tested fuels.

Reference

[1] Global Energy Statistical Yearbook 2015. *ENERDATA.* [Online] November 2015. https://yearbook.enerdata.net/.

[2] S. Bari, T. H. Lim, C. W. Yu, "Effect of preheating crude palm oil on injection system, performance and emissions of a diesel engine", Renewable Energy, Vol. 77, pp. 339-51, 2009.

[3] V.Gerhard, "Performance of vegetable oils and their monoesters as fuels for diesel engines" SAE Paper 831358, 1993.

[4] C. L. Peterson, G. L. Wagner, D. L. Auld, "Vegetable oil substitution for Diesel fuel", Trans ASAE, Vol. 26, pp. 322-327, 1993.

[5] Y. Ali, M. A. Hanna, "Alternative diesel fuels from vegetable oils", Bioresource Technology, Vol. 50, pp. 153-163, 1994.

[6] M. Canakci, J. H. Van-Gerpen, "Comparison of engine performance and emissions for petroleum diesel fuel, yellow grease biodiesel, and soybean oil biodiesel" Trans ASAE, Vol. 46, No. 4 pp. 937-944, 2003.

[7] K. F. Hansen, M. G. Jensen, "Chemical and biological characteristics of exhaust emissions from a DI diesel engine fuelled with rapeseed oil methyl ester (RME)", SAE Paper 971689, 1997.

[8] S. Murillo, J. L. Miguez, J. Porteiro, E. Granada, J. C. Moran, "Performance and exhaust emissions in the use of biodiesel in outboard diesel engines", Fuel, Vol. 86, No. 12-13 pp. 1765-1771, 2007.

[9] W. G. Wang, D. W. Lyons, N. N. Clark, M. Gautam, P. M. Norton, "Emissions from nine heavy trucks fueled by diesel and biodiesel blend without engine modification", Environment Science Technology, Vol. 34, No. 6 pp. 933-939, 2000.

[10] D. Agarwal, L. Kumar, A. K. Agarwal, "Performance evaluation of a vegetable oil fuelled compression ignition engine", Renewable Energy, Vol. 33, pp.1147-1156, 2008.

[11] S. Nagarajaa, *, K. Sooryaprakashb, R. Sudhakaranc "Investigate the Effect of Compression Ratio over the Performance and Emission Characteristics of Variable Compression Ratio Engine Fueled with Preheated Palm Oil DieselBlends",SciencDirect,doi:10.1016/j.proeps.2015.06.038

[12] Natakorn Sareekam, Siti Kartom Kamarudin, Nor Hazelah Kasmuri, "Optimization of Bio Oil from Palm Oil Fronds Via Fast Pyrolysis", Indian Journal of Science and Technology, 2016 June 9(21), Doi no: 10.17485/ijst/2016/v9i21/95232.

[13] S. Ramkumar, V. Kirubakaran, "Review on Admission of Preheated Vegetable Oil in C.I. Engine", Indian Journal of Science and Technology, 2016 Jan 9(2), Doi no: 10.17485/ijst/2016/v9i2/86417.

[14] D. Rickard, N. Thompson, "A review of the potential of bio-fuels as transportation fuels", SAE Paper 932778, 1993.

[15] L. G. Schumacher, S. C. Borgelt, D. Fosseen, W Goetz, W. G. Hires, "Heavy-Duty Engine Exhaust Emission Test Using Methyl Ester Soybean Oil/Diesel Fuel Blends", Bioresource Technology, Vol. 57, pp. 31-36, 1996.

[16] E. Buyukkaya, "Effects of biodiesel on a DI diesel engine performance, emission and combustion Characteristics", Fuel, Vol. 89, No. 10 pp. 3099-3105, 2010.

[17] A. V. Bueno, J. A. Velásquez, L. F. Milanez, "Heat release and engine performance effects of soybean oil ethyl ester blending into diesel fuel", Energy, Vol. 36, No. 6 pp. 3907- 3916, 2011.

[18] Nitin Shrivastava, S N Varma, Mukesh Pandey. A Study on Reduction of Oxides of Nitrogen with Jatropha Oil Based Bio Diesel. IJRER, Vol.2, No.3, 2012

[19] N. KapilanNatesan. The Enhancement of the Performance of a BiodieselOperated Diesel Energy Sources, Part A, 35:1648–1656, 2013 Copyright © Taylor & Francis Group, LLC ISSN: 1556-7036 print/1556-7230 online DOI: 10.1080/15567036.2010.529576

[20] N. Ladommatos, R. Balian, R. Horrocks, L. Cooper, "The effect of exhaust gas recirculation on combustion and NOx emissions in a high speed direct injection diesel engine", SAE PAPER 960840, 1996.

[21] M. Alam, J. Song, R. Acharya, A. Boehman, K. Miller. Combustion and emissionsperformance of low sulfur, ultralow sulfur and biodiesel blends in a DI dieselengine. SAE Technical Paper 2004-01-3024, 2004.

[22] A. Senatore, M. Cardone, L. Allocca, S. Vitolo, and V. Rocco. Experimental characterizationof a common rail engine fueled with different biodiesel. SAETechnical Paper 2005–01–2207; 2005.

[23] H. Jung, D. Kittelson, M.R. Zachariah. Characteristics of SME biodiesel-fueleddiesel particle emissions and the kinetics of oxidation. Environ SciTechnol2006, 40(16):4949–55.

[24] C. J. Mueller, A. L. Boehman, G. C. Martin. An experimental investigation of theorigin of increased NOx emissions when fueling a heavy–duty compression–ignition engine with soy biodiesel. SAE Technical Paper 2009-01-1792; 2009.

[25] A. S. Cheng, A. Upatnieks, C. J. Mueller. Investigation of the impact of biodieselfuelling on NOx emissions using an optical direct injection diesel engine. Int JEngine Res 2006;7:297–318.

[25] R. L. McCormick, C. J. Tennant, R. R. Hayes, S. Black, J. Ireland, T. McDaniel, et al.Regulated emissions from biodiesel tested in heavy-duty engines meeting2004 emission standards. SAE Technical Paper 2005-01-2200; 2005.

[27] Hazar Hanbey, Aydin Huseyin . Performance and emission evaluation of a CI engine fueled with preheated raw rapeseed oil (RRO)–diesel blends.