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BIO-DIESEL-A SUSTAINABLE ENERGY RESOURCES MADE FROM NON-EDIBLE OILS

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ABSTRACT

Bio-diesel the mono-alkyl esters of vegetable oils can serve as sustainable energy resources alternative to depleting fossil fuels and has gained more importance due to its clean environmental benefits, renewability and biodegradability. The proposed paper highlights the results of experimental investigations on the scope of utilizing biodiesel manufactured from Polanga and Jatropha oils as an alternative diesel fuel (IS:1460/2005) used in Indian Railways(IR). Due to its high free fatty acid contents (FFA),bio-diesel can be effectively made in multistage esterification processes using sulphuric acid as acid catalyst and potassium hydroxide as base catalyst. The production of both the bio-diesel was optimized and the effect of molar ratio of methyl alcohol to oil, reaction time, catalyst amount and reaction time were optimized during the transesterification process. To judge the quality of bio-diesel as per IS:15607/2005, different experimental investigations such as viscosity, flash point, density and calorific value etc were carried out and compared it with diesel, several blends of bio-diesel with diesel and near bio-diesel. The flash point and viscosity of bio-diesel produced from polanga oil were found to be better than the bio-diesel produced from Jatropha oil. The engine performance characteristics such as brake specific energy consumption, brake thermal efficiency and exhaust gas temperature were evaluated for different fuel blends. Exhaust gas emissions such as Carbon monoxide (CO) , Total Hydrocarbons(HC),and smoke opacity were also recorded. Results show that both the bio-diesels and bio-diesel-diesel blends can be serve as a feasible sustainable alternative and they can be used in diesel engines without major modification in engine hardware.

Keywords: Biodiesel, Indian Railways (IR) ,Jatropha-Oil, Polanga-Oil, Diesel Engine.

1. INTRODUCTION

In recent years, increased environmental awareness and energy shortage have encouraged researchers to investigate the possibility of using alternative fuels such as vegetable oils or animal fats instead of fossil fuels. Vegetable oils have considerable potential to be considered as appropriate alternative as they possess fuel properties similar to that of diesel. The major problem associated with direct use of vegetable oil is their high viscosity. One possible method to overcome the problem of high viscosity is transesterification of potential vegetable oils to produce biodiesel (esters) of respective oils.[1] This interest is because biodiesel is a biodegradable, sulphur-free, oxygenated and renewable alternative diesel fuel derived from vegetable oils or animal fats. Many researchers have reported that with the use vegetable oil biodiesel as a fuel in diesel engines, a comparable engine performance was achieved with a marked reduction in many harmful exhaust emissions in the existing diesel without significant modifications [2, 3]. However, differences in physico-chemical properties between the biodiesel and diesel fuel may change fuel injection timing and combustion characteristics. These altered physical and chemical properties may also cause exhaust emissions to differ from the optimized settings of the engine chosen by the manufacturer. In particular, the physical properties like density, viscosity and bulk modulus of the fuel used have a significant effect on fuel injection timing, combustion performance and harmful exhaust emissions [4,5, 6].

It is well established that biodiesel can be used in conventional diesel engines as blended forms without any modifications of the engine.

Many researchers had reported that engine performance was unaffected for the blend B_{20} (20% biodiesel and 80% diesel by volume). They also carried out wear assessment and long duration tests between diesel and biodiesel and confirmed that biodiesel reduce the extent of damage, coefficient of friction, wear and keeps the engine in a better health, improving the life of its vital moving components [7].

Biodiesel is a highly oxygenated fuel that can be used in diesel engines to improve combustion efficiency. Many studies have focused on the emissions of particulate matter, Nitrogen oxides (NOx), Carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbons (HC) from diesel engines fueled with biodiesel or its blends. The research indicated that HC was generally eliminated and CO was reduced roughly by 40% on using biodiesel, where NOx increased by 5-8% [8, 9].

2. EXPERIMENT

In the present work samples of biodiesels were prepared in a small scale through the process of transesterification from two different non-edible vegetable oil sources viz. Jatropha oil and Polong oil. These samples were prepared using alkali catalyzed method. Methanol (1:3 molar vegetable oil: alcohol) was mixed with KOH (1 wt% of oil) and added to the reactor containing vegetable oil slowly along with stirring. The reaction temperature was maintained at 60-65 ^{o}C. The reaction mixture was refluxed for 2-3 hours. After completion of the reaction the material was transferred to separating funnel and both the phases were separated. Upper phase was biodiesel and lower phase was glycerin. The biodiesel so obtained was purified by washing with distilled water one or more times to remove unreacted oil, catalyst or soap. After washing, the biodiesel was heated to 100-110^{o}C to get rid of residual mixture [10].

The synthesized biodiesel from two different oil sources namely Jatropha oil biodiesel (JB_{100}) and Polong oil biodiesel (PB_{100}) were tested for physico-chemical properties as per IS:15607/2005 in the Diesel-Shed Laboratory of Eastern Railway, Jamalpur. After testing of biodiesels (JB_{100} and PB_{100}) their blends with diesel were prepared in varying proportions (JB_{20}, JB_{40}, JB_{60}, JB_{80}, PB_{20}, PB_{40}, PB_{60} and PB_{80},) by volume and their physical and chemical properties were also determined and mentioned in table 1 to 3.

2.1Experimental Set up and Measurements

Initially, experiments for biodiesel production were conducted in the laboratory setup at Indian Railways Institute of Mechanical and Electrical Engineering, Jamalpur.The biodiesel reactor consists of heating mantle, reaction flask and mechanical stirrer. The working capacity of the reaction flask was 1 litre.It consisted of three necks one for stirrer, and other for condenser and inlet for the reactants as well as for the thermocouple to observe the reaction temperature.

The important variables that influence transesterification conversion were oil temperature, reaction temperature, ratio of alcohol (methanol) to oil sample, catalyst type and concentration and mixing intensity. The variable parameters were optimized and the optimized parameters were used for production of large quantity of biodiesel in a 5 litre capacity per batch as shown in Fig. 2. at IRIMEE, Jamalpur. The study also included an investigation of the impact of the biodiesel prepared from jatropha and polanga oils on engine performance and exhaust emissions characteristics, experiments were conducted on a Kirloskar made, single cylinder, air cooled comprises of a 5 kVA, 415 V, 3-phase diesel generator set.The technical specification of this engine is already mentioned in table no-4.The experimental setup(Line diagram) is already mentioned in Fig. 1. The diesel engine of 6kW, 1500 rpm is coupled to an alternator of 5 kVA capacity. The engine was loaded by putting the electrical load on the alternator. HOROBA-MEXA-324 FB was used for the measurement of CO and HC emissions from diesel engine.

Specific gravity of the samples of biodiesel and their blends were determined using hydrometer of different range as per ASTMD-445. Viscosity was measured using kinematic viscometer placed in an oiled bath thermostated at 40^{0}C. Flash point of the samples were measured as per ASTMD 93 by Penskey Marten closed cup apparatus while water contents and sediments in the samples were measured by crackling method as per ASTMD-2709.

The engine was operated on diesel first and then on biodiesels of Jatropha and Polong and their blends. Different fuel blends and diesel were subjected to performance and emission tests on the engine. The performance data were analyzed regarding thermal efficiency, Brake specific fuel consumption and emissions such as CO and HC.

3. RESULT AND DISCUSSION

The calorific values of all the biodiesels was measured and are found to be lower than that of diesel because of their oxygen content. The presence of oxygen in the biodiesel helps for complete combustion of fuel in the engine. The flash point was determined with the help of closed cup pensky marten's apparatus. The flash point of all the biodiesels is lowered by transesterification but it is still higher than that of diesel. Addition of a small quantity of biodiesel with diesel increases the flash point of diesel. Hence it is safer to store compared to diesel. The densities (as determined using hydrometers of different range) of different blends of biodiesels B20, B40, B60, B80 and B100 of jatropha, and polong biodiesels are compared with diesel. The densities of the blends were found to increase with the increasing concentration of biodiesel in the blend. However, the density of the blends B20 and B40 of jatropha and polong biodiesels were found to be much closer to diesel as compared to the blends B60, B80 and B100 and hence the blends up to B40 may be considered as an alternative fuel to diesel based on the property of density. Larger deviation in the density is observed with blends B60, B80 and B100.Similar trends were observed in the kinematic viscosity of the biodiesels measured by kinematic viscometer. The kinematic viscosity (at 40^{o}C) of blends B20, B40, B60, B80 and B100 are higher than the viscosity of diesel. The kinematic viscosity of the blends was also found to increase with the increasing concentration of biodiesel in the blend of jatropha and polong biodiesel. However, the kinematic viscosity of blends B20 and B40 were found closer to the kinematic viscosity of diesel compared to B60, B80 and B100.All these variation trends were shown in Fig.3 to 6.

In Fig. 7-11, a slight drop in brake thermal efficiency was found with biodiesels when compared with diesel. This drop in thermal efficiency may be attributed due to poor spray characteristic which is due to higher viscosity and surface tension and lower calorific value of biodiesels compared to that of diesel. The poor spray pattern effect the homogeneity of air fuel mixture which in turn lower the heat release rate their by reducing brake thermal efficiency. It was observed that the brake thermal efficiency of B20 and B40 are comparable with brake thermal efficiency of diesel. With decrease in load on the engine and increasing biodiesel concentration in the blend decreases the brake thermal efficiency compared to diesel. Jatropha oil biodiesel has shown better thermal efficiency than Polong biodiesels at every load for all the blends tested. Thus, the blends of esterified Jatropha oil and Polong oil with diesel up to 40% by volume could effectively replace diesel for running the bio-fuel plant with efficiency comparable with diesel. The exhaust gas temperature increased with increasing concentration of biodiesel in the diesel however the variation in exhaust gas temperature was less at lower loads but more pronounced at higher loads. This may be attributed due to advance in injection timing by the use of biodiesel compared to neat diesel operation. As result the injection of biodiesel fuel in the combustion chamber start earlier compared to diesel with delivery of greater volume of fuel into combustion chamber causing short time period for the combustion and probably lesser time for cooling of the engine resulting in high temperature inside the cylinder compared to diesel. This high temperature facilitate in the oxidation of inactive nitrogen present in the air to form more NOx due to inherent free oxygen present in the biodiesel resulting in increased formation and emission of NOx.

Biodiesel gives less smoke density from no load to full load and for all the blends tested compared to diesel. This could be due to inherent oxygen molecule present in the biodiesel chain which enhanced its burning compared to diesel. When percentage of blends of biodiesel increases, smoke density decreases. It also decreases with increasing load. Similar trends were observed with carbon monoxide and HC as shown from Fig.12 to 23 respectively, this may be attributed due to enhanced burning and proper combustion of biodiesel due to oxygen present in the chain.

Table 1: Specification of biodiesel and diesel fuel

Properties and units	**Biodiesel IS:15607/2005**	**Diesel (HSDOil) IS:1460/2005**
Density(Kg/m^3 at 25^{0}C	870-900	850
Calorific value. MJ/Kg	---	44
K.Viscosity cSt at 40^{0}C	2.0-6.0	2.0-5.0
Flash point ^{0}C	130 Min	35^{0}C
Pour point ^{0}C	42.6	873

Table 2: Properties of biodiesels and its blends.

Biodiesel and its blends	**Calorific value MJ/kg**	**Density (Kg/m^3)at 25^{0}C**
JB20	43.7	852
JB40	43.5	854
JB60	43.0	860
JB80	42.9	866
JB100	42.6	873
PB20	43.1	852
PB40	42.8	854
PB60	42.3	860
PB80	41.9	862
PB100	41.3	869

Table 3: Properties of biodiesels and its blends.

Biodiesel and its blends	**Viscosity (Cst) at 40^{0}C**	**Flash point (^{0}C)**	**Pour point (^{0}C)**
JB20	3.02	88	3.3
JB40	3.41	97	3.4
JB60	3.64	119	3.6
JB80	3.98	131	3.9
JB100	4.23	148	4.2
PB20	2.98	86	3.0
PB40	3.30	91	3.2
PB60	3.61	96	3.4
PB80	3.72	109	3.6
PB100	3.99	111	3.6

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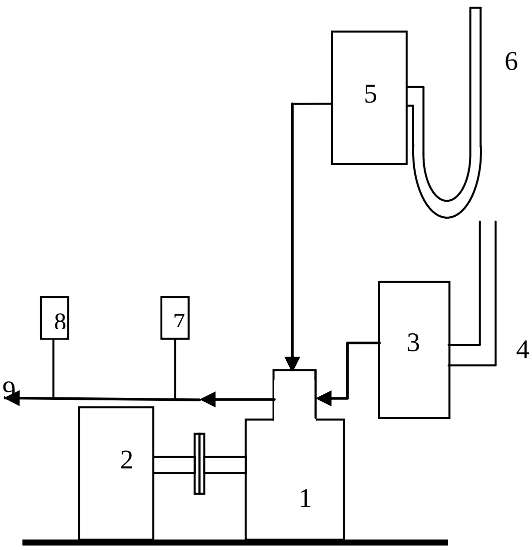
Table 4: Technical Specification of the engine..

Particulars	
Diesel Engine	Kirloskar make Single cylinder,4-stroke,vertical,air cooled DI engine.
Bore	95mm
Stroke	110mm
Compression ratio	17.5:1
Rated power	6kW
Rated rpm	1500
Generator (Alternator)	5kVA,415V,3-phase,0.8PF
Feed Stock	Jatropha and Polanga oil biodiesels
Gas Analyzers	HOROBA-MEXA-324 FB for the measurement of CO and HC whereas AVL 437 smoke meter was used to measure the smoke density.



1. Engine 4. Burette 7.Exhaust Analyzer
2.Alternator 5. Air Box 8. Smoke Meter

3. Fuel Tank 6.Manometer 9. Exhaust Flow

Fig.1. Experimental Setup (Line Diagram)

Fig. 2. Biodiesel plant

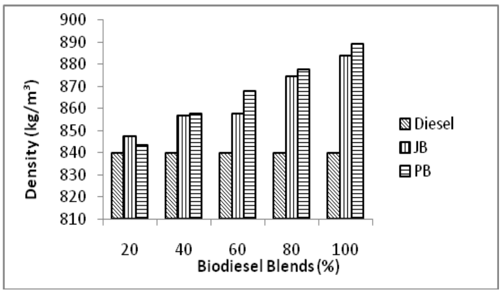


Fig. 3. Variation of density with blends of biodiesels.

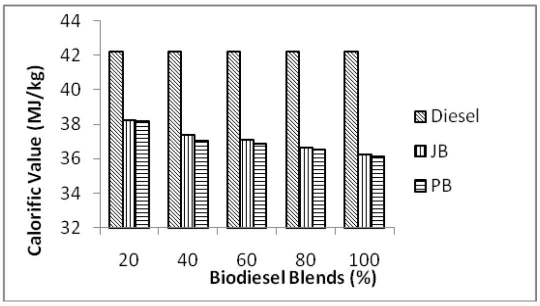


Fig.4. Variation of caloric value with blends of biodiesels.

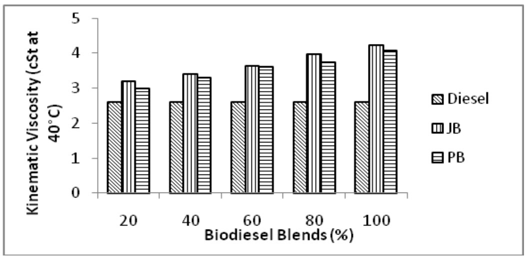


Fig.5. Variation of K.Viscosity with blends of biodiesels.

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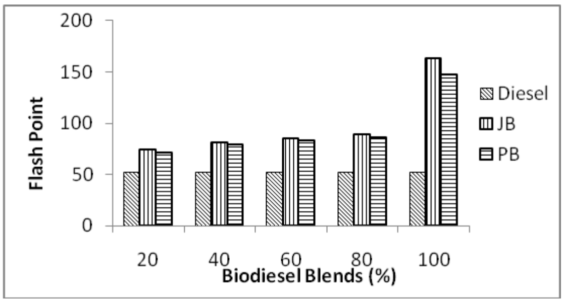

Fig.6. Variation of Flash point with blends of biodiesels

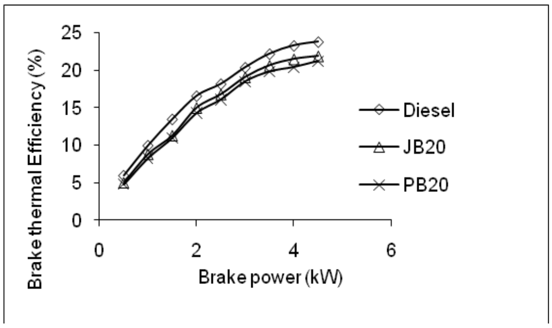

Fig.7.Brake thermal efficiency and Brake power with biodiesel blend of B20

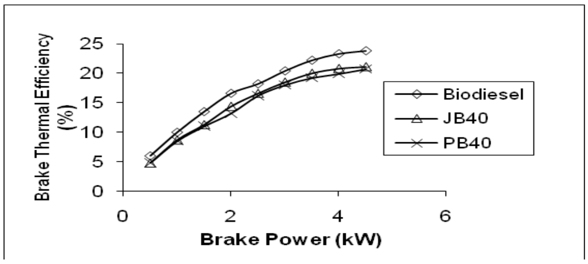

Fig.8. Brake thermal efficiency and Brake power with biodiesel blend of B40

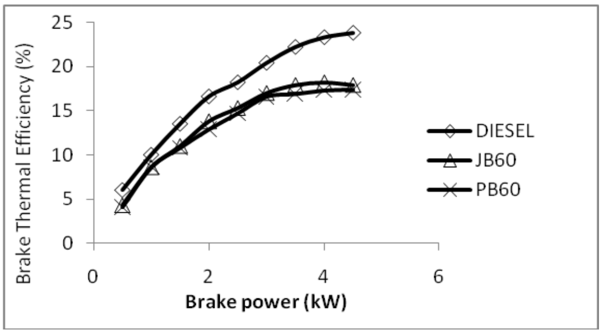

Fig 9: Brake thermal efficiency and Brake power with biodiesel blend of B60

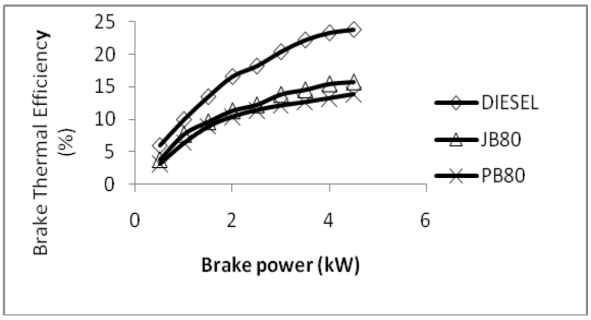

Fig.10. Brake thermal efficiency and Brake power with biodiesel blend of B80

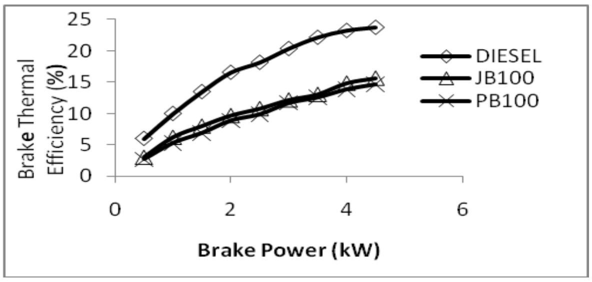

Fig.11. Brake thermal efficiency and Brake power with biodiesel blend of B100

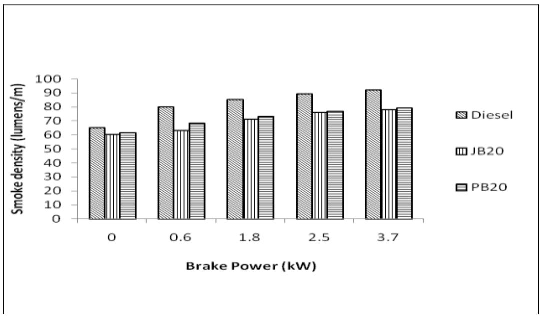

Fig. 12.Smoke density vs Brake power for 20% blends

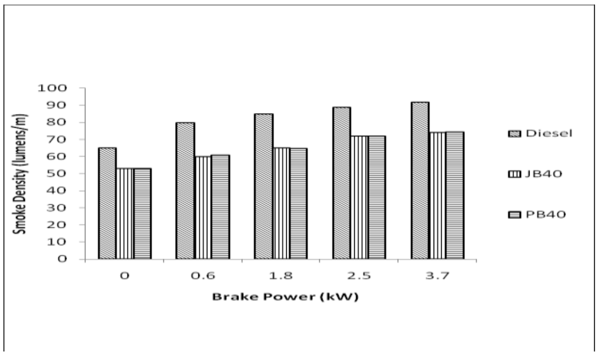

Fig. 13.Smoke density vs Brake power for 40% blends

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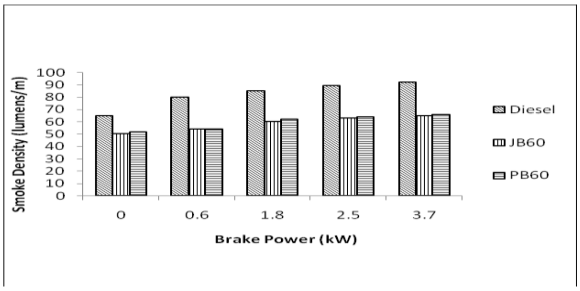

Fig. 14.Smoke density vs Brake power for 60% blends

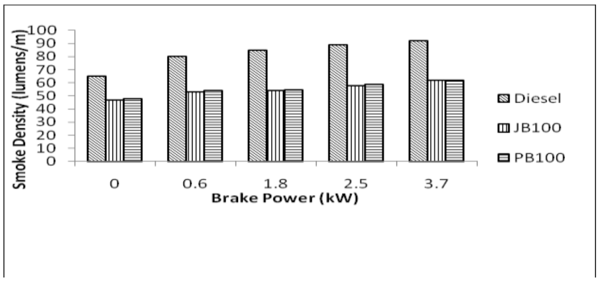

Fig. 15.Smoke density vs Brake power for 100% blends

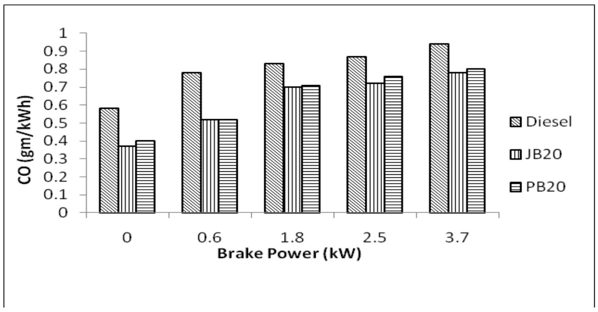

Fig. 16.CO vs Brake power for 20% blends

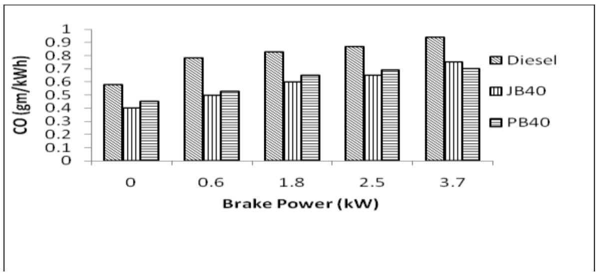

Fig. 17.CO vs Brake power for 40% blends

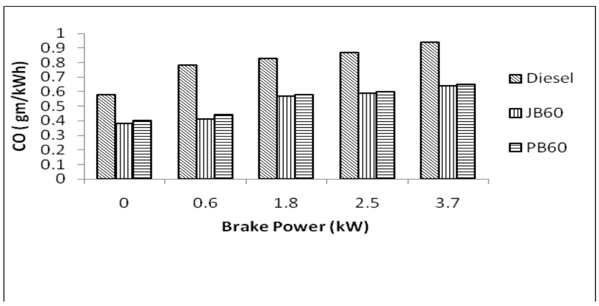

Fig. 18.CO vs Brake power for 60% blends

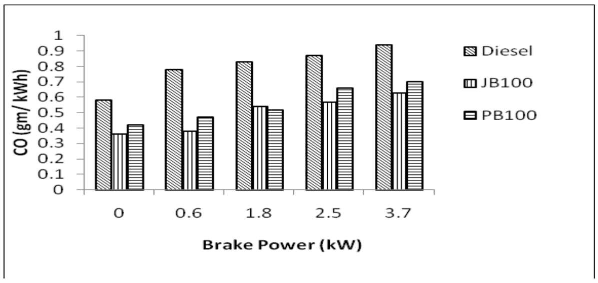

Fig. 19.CO vs Brake power for 100% blends

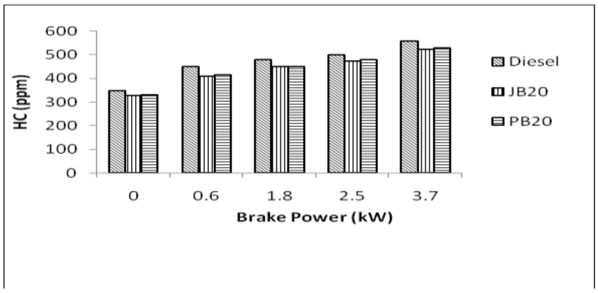

Fig. 20. HC vs Brake power for 20% blends

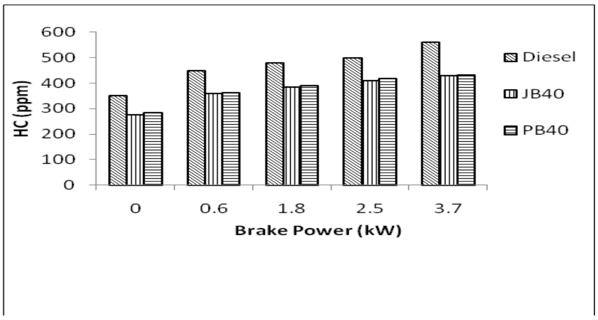

Fig. 21. HC vs Brake power for 40% blends

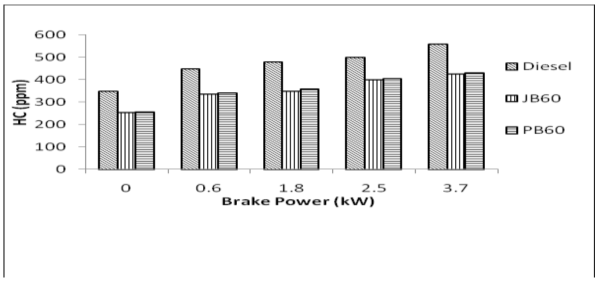

Fig. 22. HC vs Brake power for 60% blends

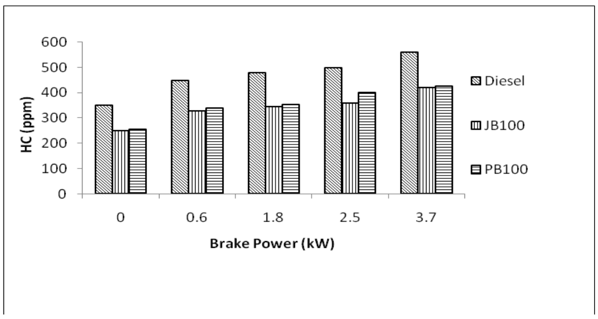

Fig. 23. HC vs Brake power for 60% blends

4. CONCLUSIONS

Following conclusions are drawn based on the experiment results obtained while operating in single cylinder diesel engine fueled with biodiesel derived from locally available Jatropha and Polanga oils through a transesterification.

Jatropha and Polanga based biodiesels can be an attractive option for the substitute of petro-diesel because of their desirable properties. The density and viscosity of vegetable oil gets drastically reduced after transesterification.

The density and viscosity of biodiesel were very close to petroleum diesel oil. The flash point is greater than that of diesel whereas Calorific value is slightly lower than that of diesel.

As evident from Fig.7 to 11. the Brake thermal efficiency of B20 and B40 blends are better than B100 but still inferior to diesel. Properties of different blends of biodiesel are close to the diesel but B20 is giving the optimum results comparable to diesel.

CO and HC emissions at different loads were found to be higher for diesel, compared to blends of biodiesel with diesel.

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NOMENCLATURE

Symbol	
IR	Indian Railways
PB	Polanga oil biodiesel
JB	Jatropha oil biodiesel
HC	Hydrocarbon
CO	Carbon monoxide
kW	Brake power

AUTHOR BIOGRAPHY

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Dr. Arbind kumar is working as Professor and Head in the Department of Mechanical Engineering, Birla Institute of Technology, Mesra, Ranchi. He obtained his Ph.D Degree from Regional Institute of Technology,Jamshedpur in the year 2001. He has to his credit over 20 International Publications and 08 National Publications in Journals. His area of research is new and renewable energy.

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