

Reducing the Environmental Pollution from Diesel Engine Fuelled with Eco- Friendly Biodiesel Blends

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Abstract: Diesel engines are widely used for their low fuel consumption and better efficiency. Fuel conservation, efficiency and emission control are always the investigation points in the view of researchers in developing energy system. India to search for a suitable environmental friendly alternative to diesel fuel. The regulated emissions from diesel engines are carbon monoxide (CO), Hydrocarbons (HC), NO_x and Particulate matter. It creates cancer, lungs problems, headaches and physical and mental problems of human. This paper focuses on the substitution of fossil fuel diesel with renewable alternatives fuel such as Biodiesel. Biodiesel is much clear than fossil diesel fuel and it can be used in any diesel engine without major modification. The experiment was conducted in a single-cylinder four-stroke water-cooled 3.4 kW direct injection compression ignition engine fueled with non-edible Pongamia oil biodiesel blends. The experimental results proved that up to 40% of Pongamia oil biodiesel blends give better results compared to diesel fuel. The AVL 444 di-gas analyzer and AVL 437 smoke meter are used to measure the exhaust emissions from the engine. The observation of results, non-edible Pongamia biodiesel blended fuels brake thermal efficiency (3.59%) is improved and harmful emissions like CO, unburned HC, CO₂, Particulate matter, soot particles, NO_x and smoke levels are 29.67%, 26.65%, 33.47%, 39.57%, +/- 3.5 and 41.03% is decreased respectively compared to the diesel fuel. This is due to biodiesel contains the inbuilt oxygen content, ignition quality, carbon burns fully, less sulphur content, no aromatics, complete CO₂ cycle.

Keywords: Diesel engine, NO_x reduction, Biofuel, oxygenated fuel, Environmental Pollution.

1. Introduction

Ever-increasing demand, not commensurate with the source, of petroleum-derived fuels (diesel) and a threat to the global environment, has given an impetus for researchers to find a viable and eco- friendly alternative fuel for the energy-hungry

countries to meet the energy requirement. The switch to biodiesel brings a sustainable alternative source for diesel fuel. Biodiesel is a renewable and environmental friendly fuel that is derived from vegetable oil. vegetable oils cannot be used as fuel directly owing to

the presence of free fatty acids, phospholipids, Sterols, water, Odorant and other impurities which causes potential problems without engine modification and have served disadvantages like poor atomization due to high viscosity, incomplete combustion and carbon deposit build upon several engine parts such as injectors, piston rings, cylinder walls, and valve seats. However, the problem of high viscosity can be solved by using a number of techniques like preheating, micro emulsion, pyrolysis, blending, supercritical method, and transesterification methods. Among these, the transesterification process has been widely used to prepare biodiesel from vegetable oil and animal fats. Transesterification process reduces viscosity and it enhances the fuel properties. [1]. In general, vegetable oil contains 97% of triglycerides and 3% of di- and monoglycerides and fatty acids. Transesterification is the chemical reaction between triglycerides and short-chain alcohol in the presence of a catalyst to produce mono-ester. The long and branched-chain triglyceride molecules are transformed into mono-ester and glycerin. Transesterification or alcoholysis is the displacement of alcohol from one ester by another alcohol in a process similar to hydrolysis. Transesterification is the process of using alcohol (methanol or ethanol) in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to chemically break the molecule of the raw oil into methyl or ethyl esters of the oil with glycerol as a by-product. This process has been widely used to reduce the viscosity of triglycerides. The transesterification reaction requires a catalyst for better efficiency of the process [2]. The transesterification of triglycerides by methanol, ethanol, propanol, and butanol has proved to be the most promising process. Methanol is the commonly used alcohol in this process, due to its low cost. The important variables affecting the esters yield during the transesterification reaction are, catalyst type and concentration, the molar ratio of alcohol to oil and type of alcohol, effect

of reaction time and temperature and mixing intensity. The experiments for kinetic data on the transesterification reaction. This is achieved by conducting the reaction at various temperatures and molar ratios. They found that acid catalyst transesterification was slower than alkali transesterification. The compared homogeneous and heterogeneous catalytic systems [3]. They reported that the homogeneous catalyst process requires mild operation conditioning while heterogeneous catalyst process required a high temperature of reaction and higher of methanol to oil ratio. The three principal variables, the molar ratio of methanol to oil, amount of catalyst and reaction temperature affecting the yield of acid-catalyzed production of methyl ester (bio diesel) from crude palm oil. The biodiesel was extracted in batch and the continuous acetone-butanol-ethanol formation and its fuel properties were analyzed. The optimized variables were 40:1 methanol/oil (mole/mole) with 5% H₂SO₄ (volume/weight) reacted at 95° C for 9 hours gave a maximum ester yield of 97%. The biodiesel prepared from mahua oil by transesterification process using sulphuric acid (H₂SO₄) with a catalyst 5% weight/weight, 20:1 molar ratio of ethanol to mahua oil at a temperature of 72- 75 ° C for a period of 5 hours. The ester was washed with salt water (5% NaCl solution) and the product was dried at 110° C in an oven for an hour to remove the traces moisture. The bio diesel produced from palm kernel oil by transesterification process using KOH as a catalyst for 10g of ethanol for 100g of palm kernel oil at a temperature of 60 ° C for a period of 100 minutes to produce a yield of 92%. Kaemee and Anju Chadha (2005) reported that KOH catalyzed transesterification of crude pongamia oil resulted in the high conversion of 92% in 1.5 hours at 60° C with a molar ratio 1:10 (oil: methanol) [4]. A survey on biodiesel engine performance and exhaust emissions researcher published after the year 2007 determined that 85% of the literature

indicates that the use of biodiesel reduced CO, HC, and PM emissions due to the higher oxygen content of biodiesel compared to diesel fuel [5]. From the above literature review, it is clear that majority of the researchers have been focused on transesterification process of various types of vegetable oils for production of biodiesel. The main focus of this paper is to produce biodiesel from Pungamia oil by transesterification process as fuel and also to evaluate the properties of pungamia biodiesel blends with diesel (B20, B40, B60, B80 and B100) in comparative with diesel fuel.

2. Characteristics of Pungamia Tree

Pongamia is a native of Central America. It is a big shrub growing to a height of about 3 meters and branches spread up to 4.5 meters as shown in Figure 1(a). It is well adapted to arid and semi-arid conditions, marginal soils with low nutrient content, medium altitude (90-500m), moderate temperature (20-28°C) and low to ready rain fall (300-1000 mm or more). It grows in well drained soils but does not thrive in wet lands. The hardy plant has moderate drought tolerance.

Propagation by seeds or cuttings starts bearing with in the first year of planting, but yield stabilizes after five years and continues up to 50 years. The oil is non edible and used as fuel, varnish, pesticide, additive in soap making tanning, folk / traditional medicine. The fruit contain 35-47% shell and 53-65% kernel. The growth of Pungamia seed at various stages is shown in Figure 1(a) to 1(d).

The Pungamia seed which contains oil about 35% is shown in Figure 1(d). Due to toxicity its cake can't be used as animal feed and is used as organic manure. The normal planting is about 3 plant per meter for soil conservation 2000 plants per ha in poor soils and for plantation it varies from 4000 to 6000 plants per ha as shown in Figure 1.

The adaptive trials were under taken at different plants of India such as Hissar, Hyderabad, and Bangalore&Sardar krishnagar. Hissar trails gave seed yield of 1733 Kg/ha. In Narkoda farm near Hyderabad having typical marginal red soil planted with spacing of 3x1.5m (ie 2222 plants per ha) gave a maximum yield in individual tree of 760g.

3. Properties of Pungamia Oil

The fuel properties of pungamia oil compared with diesel has been summarized in Table1. It indicated that kinematics viscosity of Pungamia oil comes around 49.9 cSt, at 38 °C. The high viscosity of Pungamia oil is due to its large molecular mass in the range of 600 – 900 which is about 20 times higher than that of diesel fuel.

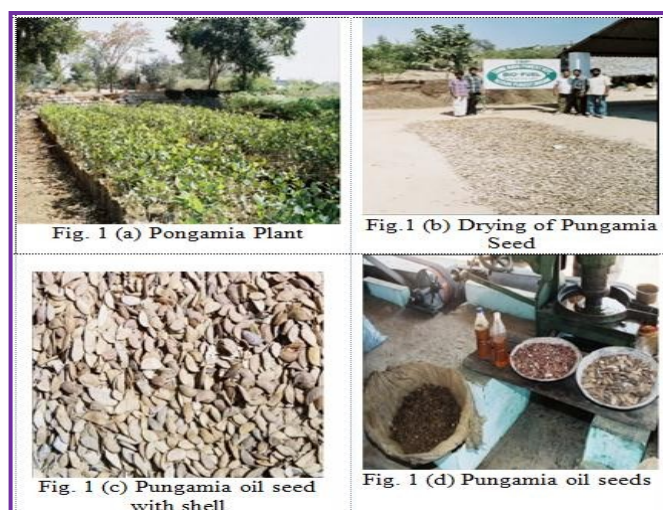


Figure 1. Pungamia characteristics

Table 1. Properties of Pungamia oil compared with diesel (before transesterification)

Properties	Diesel	Pungamia Oil
Cetane No.	45 – 55	40-45
Specific gravity	0.84	0.953
Viscosity (cSt)	45.9	49.9
Calorific value (MJ/kg)	43	35.43
Flash point °C	50	195
Carbon residue %	86	74.45

The flash point of pungamia oil is very high (i.e. 195 °C).

4. Methodology

To produce bio diesel from non-edible Pungamia oil and study the fuel properties of different blend ratios of bio diesel with diesel after the properties of fuel study the engine performance and emission characteristics of bio diesel-diesel blended fuels with and without EGR. Finally to find the best blend ratio depends upon the performance and emission characteristics of the engine.

5. Bio-Diesel Production

5.1 Transesterification

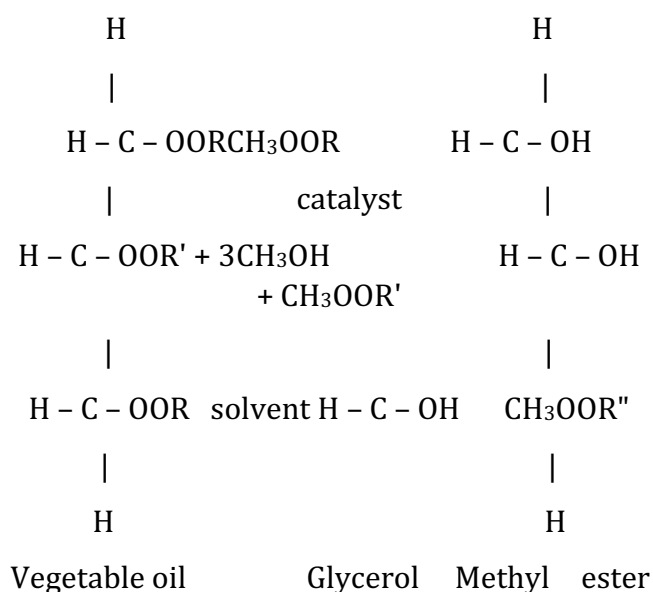
Transesterification is the reaction of a fat or oil with an alcohol to form esters and glycerol. A catalyst is usually used to improve the reaction rate and yield. Because the reaction is reversible, excess alcohol is used to shift the equilibrium to the product side.

Alcohols are primary and secondary monohydric aliphatic alcohol having 1-8 carbon atoms. Among the alcohols that can be used in the transesterification process are methanol, ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are used most frequently, especially methanol because of its low cost and its physical and chemical advantages. It can quickly react with triglycerides and NaOH is easily dissolved in it. To complete a transesterification stoichiometrically, a 3:1 molar ratio of alcohol triglycerides is needed. In practice, the ratio needs to be higher to drive the equilibrium to a maximum esters yield. The alkalis includes NaOH, KOH, carbonates and corresponding sodium and potassium alkoxides such as sodium meth oxide, sodium ethoxide, and sodium prop oxide and sodium but oxide. Sulfuric acids and hydrochloric acid are usually used as acid catalysts. Lipases also can be used as bio-catalysts. Alkali-catalyzed

transesterification is much faster than acid-catalyzed transesterification and is most often used commercially [7]. For an alkali-catalyzed transesterification, the glycerides and alcohol must be substantially anhydrous because water makes the reaction partially change to saponification, which produce soap. The Figure. 2 shows the line diagram of transesterification unit used to produce the bio diesel from pungamia oil.



Figure 2. Transesterification unit for produce bio diesel from pungamia oil



The yield of methyl ester was 775ml. With the increase in the concentration of catalyst, there was decrease in the yield of methyl esters and formation of soap. This has increased the viscosity of the reactants and lowered the yield. Table 2 summarizes the fuel properties of bio-diesel from Pungamia oil compared with diesel.

Table 2. Properties of Bio-Diesel from Pungamia Oil Compared with Diesel (After Transesterification)

Properties	Diesel	Bio-Diesel (Methyl Ester)
Cetane No.	45 – 55	48
Specific gravity	0.83	0.934
Viscosity cSt	4.7	6.3
Calorific value (MJ/kg)	42	40
Flash point .C	50	80
Carbon residue %	86	83

6. Specification of the Engine

The test has been carried out in a single cylinder, four stroke, 3.7 KW (5HP), Water-cooled, direct injection, and naturally

Table 3. Experimental Engine and Engine Specifications

General Details	4 stroke, water cooled, direct injection, naturally aspiration, C.I. Engine
Maximum Power	3.7 kw = 5HP
Make	Kirloskar Av.1
Number of Cylinders	1s
Bore x Stroke	80 x 110. (mm)
Speed	1500 rpm
Fuel used	Diesel, bio-diesel, and its blends
Eddy Current Dynamometer	Load
AVL 444 – 5 Gas Analyzer	Emission (HC, CO, CO2 and NOx)
AVL 437 Standard Smoke Meter	Smoke density

Aspirated C.I. engine loaded with eddy current dynamometer. The fuel flow rate is measured by noting down the time taken for the consumption of known quantity of fuel (10cc) from a burette. The experimental engine and the engine specifications are shown in Figure 5 and the Table 3 respectively.

The engine is started and allowed to warm-up for about 10 minutes. The engine is tested under six discrete part load conditions. Viz: 0%, 20%, 40%, 60%, 80%, and 100%. For all the loads, engine speed was constant at 1500 rpm. The time taken for 10cc of fuel consumption is noted for each load, for diesel, B20, B40, B60, B80 and B100.

The exhaust gas was made to pass through the probe of exhaust gas analyzer for the measurement of CO, CO₂, HC, NO_x and later passed through the probe of diesel smoke meter for the measurement of smoke density.

7. Results for Performance Calculation

Figure 4 shows the variation of specific fuel consumption with brake power of the engine for diesel, bio-diesel blends and bio-diesel. The specific fuel consumption decreased with the increase in brake power.

One possible explanation for this reduction could be due to the higher percentage of increase in brake power compared to fuel consumption. 20% higher than that of diesel.

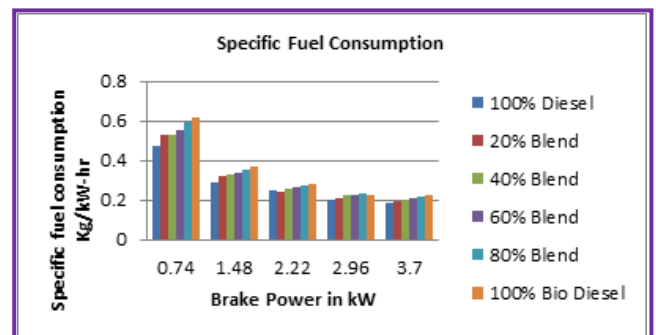


Figure 4. Brake Power (Vs) Specific Fuel Consumption

The specific fuel consumption for B20 and B40 was 10-11% higher than that of diesel. In case of B60-B100 the specific fuel consumption was 13 –20% higher than that of diesel. This is due to the lower calorific value with an increase in bio-diesel percentage in the blends.

Figure 5 shows the variation of brake thermal efficiency with brake power of the engine for diesel, bio-diesel blends and bio-diesel. In all cases, it increase with an increase in brake power. This was due to a reduction in heat loss and increase in brake power. The maximum brake thermal efficiency obtained was 42.26% and 41.09% for B20 and B40 respectively. This is less than that of diesel (43.32%) the maximum brake thermal efficiency obtained for B60, B80 and B100 were 38.39%, 37.52%, and 36.63% respectively. This lower brake thermal efficiency obtained for B20 to B100 could be due to poor mixture formation as a result of reduction in calorific value, higher viscosity and density with an increase in bio-diesel percentage in the blend.

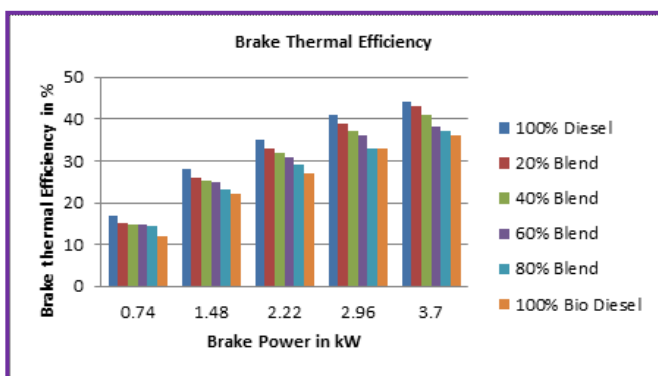


Figure 5.

8. Performance & Emission Characteristics

Figure 6 shows the variation of CO emission with brake power of the engine for diesel, bio-diesel blends, and bio-diesel. The amount of CO has decreased at part load, and again increased at full load condition for all blend ratios. This may be attributed to drastic reduction in air/fuel ratio from part load to full load. It is observed that CO emission for bio-diesel blends and bio-diesel were lower than

net diesel, for all load conditions. This reduction indicated more complete oxidation of the blends and bio-diesel

Figure 7 shows the variation of CO₂ emission with brake power of the engine for diesel, bio-diesel blends and bio-diesel. The CO₂ emission increased with an increase in brake power. The amount of CO₂ has decreased in increasing the blends ratio, compared to net diesel. This is due to relatively lower carbon content in the same volume of fuel consumed at the same engine load. Bio-diesel contains oxygen in structure which burns clearly all the fuels.

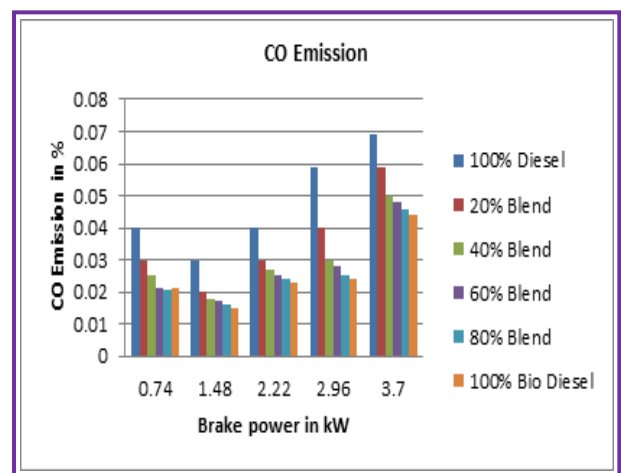


Figure.6 Brake Power (Vs) CO Emission

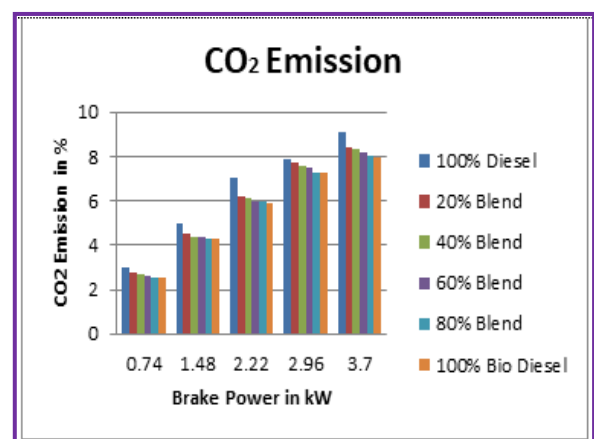


Figure.7 Brake Power (Vs) CO₂ Emission

Figure 8 shows the variation of unburnt hydrocarbon (HC) emission with brake power of the engine for diesel, bio-diesel blends, and bio-diesel. The HC emissions of all fuels are lower in partial engine load. This is due to relatively less oxygen available for the reaction when more fuel is injected into the engine

cylinder at higher load. The amount of HC has decreased while increasing the blends ratio compared to diesel. This is due to the oxygen content of the fuel coming into picture as it enhances the combustion process to burns clearly all the fuels.

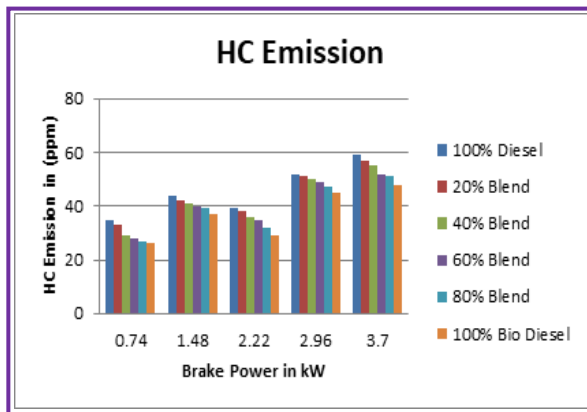


Figure. 8 Brake Power (Vs) Hydro Carbon Emission

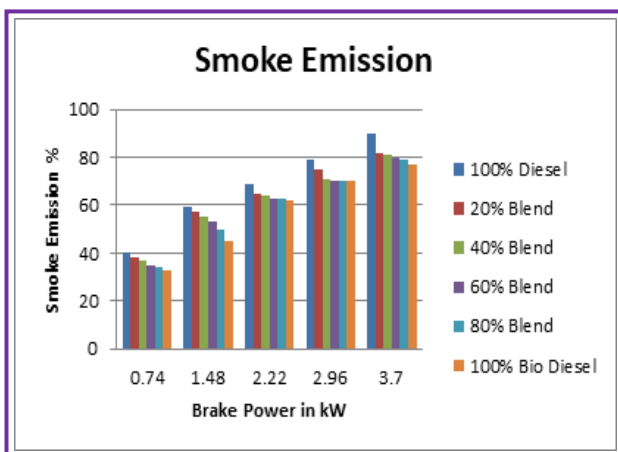


Figure. 9 Brake Power (Vs) Smoke Density

Figure 9 shows the variation of smoke emission with brake power of the engine for diesel, bio-diesel blends and bio-diesel. The smoke density increased with the increased brake power. The amount of smoke density decreased in increasing the blends ratio compared to net diesel. This is due to the oxygen content of bio diesel in structure. There is an increased efficiency of combustion even for the petroleum fraction of the blend. The improved combustion efficiency lowers smoke emissions.

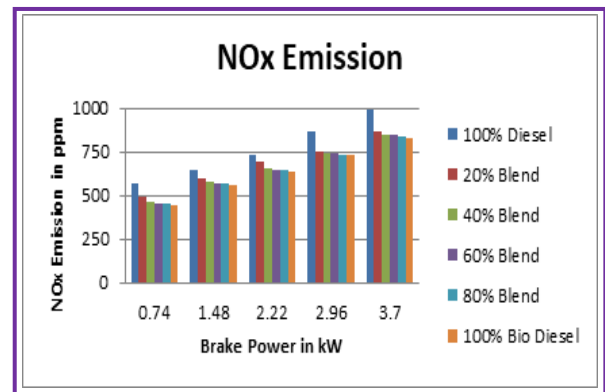


Figure. 10 Brake Power vs NOx Emission

8. Environmental Eco Friendly Impact

- Bio diesel is non-toxic.
- Bio diesel degrades four times faster than diesel.
- Its oxygen content improves the bio-degradation process.
- Pure bio diesel degrades 85 - 88% in water.
- Blending of bio diesel with diesel fuel increases engine efficiency.
- The uses of bio diesel can extend the life of diesel engine because it has more lubricating property than petroleum diesel fuel.
- Bio diesel obtained from crops produces favorable effects on environment, such as decrease in acid rain and in the greenhouse effect caused by pollution.
- Bio diesel is termed as a "carbon neutral" as bio diesel yielding plants absorbs more carbon dioxide from the atmosphere during the process of photosynthesis than they add to the atmosphere when used as fuel in compression ignition engines.
- Bio diesel can be used alone or mixed in any ratio with petroleum diesel fuel.
- It helps to reduce a country's reliance on crude oil imports and support agriculture by providing employment and market opportunities for domestic crops.
- The risk of handling, transporting and storing of bio diesel are much lower than petro-diesel.

- The larger reductions in Poly aromatic hydrocarbon (PAH) as bio diesel contains no aromatics and no PAH compounds
- By-product of crude glycerol obtained from transesterification process can be used for manufacturing medical and industrial chemicals.
- 40% of bio diesel blended with 60% of diesel fueled with diesel engine reduces the harmful exhaust emission from engine without sacrificing the power output.

9. Conclusion

Based on the result of this study it was found that blends of Pungamia oil methyl ester (bio-diesel from Pungamia oil) with diesel reduced emissions in diesel engines such as CO, CO₂, HC and smoke on an average 20% to 80% by increasing the blends ratio. The power output of the engine is not affected for different blends compared with the net diesel. The specific fuel consumption for B20 and B40 was 10-11% higher than diesel. This was due to lower calorific value of blended fuels. Hence it can be concluded that the blends of methyl ester of Pungamia oil with diesel upto 40% by volume could replace diesel as fuel for running diesel engines for getting less emission without sacrificing the power output and this will help in controlling the human health hazardous emissions from the diesel engine to great extent.

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