A Review on Honge (Pongamia Pinnata) Biodiesel as an Alternative fuel for Diesel Engine

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Abstract

Self reliance in energy is vital for overall economic development of our country. The need to search for alternative sources of energy which are renewable, safe and non- polluting assumes top priority in view of the uncertain supplies and frequent price hikes of fossil fuels in the international market. And we can say that the Diesel engines are widely used light, medium and heavy duty vehicles and power generation in heavy machinery, because of higher thermal efficiency and the ability for lean operation. The lean burn capability helps to lower the carbon monoxide (CO) and Hydro carbon (HC) emissions compared to those of a spark ignition (SI) engine. Due to the Agricultural origin of the biofuels they emit less CO_2 (Carbon di oxide) and CO (Carbon monoxide). As the Biofuels are made from renewable source, they have good environmental benefits. Biodiesel (fatty acid methyl ester) which is derived from triglycerides by trans-esterification, has attracted considerable attention during the past decade as a renewable, biodegradable and nontoxic fuel. In India, there are many trees bearing oil like ratanjot (jatropha curcus), mahua (madhuca indica), pilu (salvodara oleoids), nahor (mesua ferralina), kokam (garcinia indica), karanja (pongamia pinnata) and rubber seed (heveabrasilensis) etc. Based on various studies, this paper generally found that Pongamia Pinnata biodiesel can be used in CI engines as alternative fuel. Among these species, which can yield oil as a source of energy in the form of biodiesel, Pongamia pinnata has been found to be one of the most suitable species due to its various favourable attributes like its hardy nature, high oil recovery and quality of oil, etc. As the acid value of this oil is high, so that we have to reduce it by the process of esterification followed by trans-esterification. The methyl ester produced by this way gives the good result. Several processes for biodiesel fuel production have been developed, among which trans-esterification using alkali as catalyst gives high level of conversion of triglycerides to their corresponding methyl ester in a short duration. Based on various studies, this paper generally found that Pongamia Pinnata (Karanja) biodiesel can be used in CI engines as alternative fuel.

Keywords: *Diesel engines, Emission, Biofuels, Pongamia pinnata, Biodiesel.*

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1. INTRODUCTION:

There are variety of renewable source of energy like solar energy, Wind energy, geothermal energy, Ocean thermal energy and Wood energy etc. In the last few years interest & activity has grown up around the globe to find a substitute of fossil fuel. [1]. According to Indian scenario the demand of petroleum product like diesel is increasing day by day hence there is a need to find a solution. So bio-energy which is generated from the bio-fuels are viewed as a genesis in upcoming future.[2]. The use of edible oil to produce biodiesel in India is not feasible in view of big gap in demand and supply of such oil. Under Indian condition only non-edible oil can be used as biodiesel which are produced in appreciable quantity and can be grown in large scale on non-cropped marginal lands and waste lands.[3]. Under Indian condition only non-edible oil can be used as biodiesel which are produced in appreciable quantity and can be grown in large scale on non-cropped marginal lands and waste lands. The try for various alternative fuels in place of hydrocarbon oils are mainly biogas, producer gas, ethanol, methanol and vegetable oils. Non-edible oils like jatropa, karanja and mahua contain 30% or more oil in their seed, fruit or nut. India has more than 300 species of trees, which produce oil bearing seeds. By comparing the fuel properties with that of diesel the vegetable oil has an advantage over others. The idea of using vegetable oil as fuel has been around from the birth of diesel engine.[4].

Biodiesel, an alternative diesel fuel, is made from renewable biological sources such as vegetable oils and animal fats. It is biodegradable and nontoxic, has low emission profiles and so is environmentally beneficial.

One hundred years ago, Rudolf Diesel tested vegetable oil as fuel for his engine . With the advent of cheap petroleum, appropriate crude oil fractions were refined to serve as fuel and diesel fuels and diesel engines evolved together. Bio-fuels are fuels produced by a number of chemical / biological processes from biological materials like plants, agricultural wastes etc. Bio-diesel can be used as a pure fuel or blended with petroleum diesel depending on the economics and emissions. Biodiesel fuel has the potential to reduce the level of pollutants and the level of potential or probable carcinogens.[5].

2. NEED FOR KARANJA OIL :

Pongamia pinnata (L.) Pierre, an arboreal legume, is a member of the subfamily Papilionoideae, more specifically the Millettieae tribe. This medium-size tree is indigenous to the Indian subcontinent and south-east Asia, and has been successfully introduced to humid tropical regions of the world as well as parts of Australia, New Zealand, China and the USA.[6]. The current estimated potential of this oil is nearly 30,000 tons per annum in India. The kernel contains 27–39% oil. The freshly extracted oil is yellowish orange to brown. It rapidly darkens on storage. It has a disagreeable odour and a bitter taste. The oil is mainly used as raw material for soaps. The oil is also known for its curative effect for skin problems such as leucoderma, psoriasis, scabies and skin itches [7]. India has a vast number of minor oils but only few of these minor oils have been evaluated for their nutritional quality. Nutritional and economic feasibility studies of minor oils have been stimulated due to the shortage, and high prices are paid for edible oils. Karanja oil is such an oil and it contains nearly 5% of nonlipids predominating karanjin (1.25%) and pongamol (0.85%), which are furanoflavanoids in structure and toxic in nature. Various processes have been reported for the removal of nonlipids from karanja oil have reported the nutritional quality of refined karanja oil but their study indicates poor growth performance, altered lipid metabolism, abnormalities in the liver etc. In the present study efforts have been made to improve karanja oil to an edible quality and study the nutritional quality of refined karanja oil along with groundnut oil as control because of analogous fatty acid composition. The growth response, lipid profile of liver tissue and serum of the rats have been investigated. [8].

2.1. RENEWABLE AND SUSTAINABLE SOURCES OF BIODIESEL PONGAMIA PINNATA :

At a time when society is becoming increasingly aware of the declining reserves of oil for the production of fossil fuels, it has become apparent that biofuels are destined to make a substantial contribution to the future energy demands of the domestic and industrial economies. Pongamia pinnata will impact most significantly through the extraction of seed oil for use in the manufacture of biodiesel. The potential of P. pinnata oil as a source of fuel for the biodiesel industry is well recognized [9,10,11]. Moreover, the use of vegetable oils from plants such as P. pinnata has the potential to provide an environmentally acceptable fuel, the production of which is greenhouse gas neutral, with reductions in current diesel engine emissions [12].

2.2. ANALYSIS OF BIODIESEL :

Analysis of biodiesel Ester content of Karanja methyl esters was determined using high-performance liquid chromatography, Perkin Elmer Series 200 equipped with a refractive index detector (Shodex RI 71). A Spheri-5 C-18 column (PerkinElmer Brownlee Column) (220_4.6mm with 5 mm particle size) with 1ml min_1 flow rate of methanol was used as a carrier solvent with the column kept at 40 1C. The sample injection was 20 ml and comparing their respective standards made peak identification. The fatty acid methyl esters composition is given in Table 1. The fuel properties of Karanja methyl esters were determined as per the ASTM (D6751) standards. Karanja Seed Oil Cake is by-product after oil extraction, which otherwise goes waste or as fertilizers, is used as Precursor for Activated Carbon Preparations. Pongamia oil contains oleic acid (44.5–71.3%) as the major fatty acid followed by linoleic (10.8–18.3%), palmitic (11.65%) and stearic (2.4–8.9%) acids. Lilonic acid (16.64) and Free fatty acid (mgKOHg_1) (5 – 20). In addition to these four fatty acids, Pongamia oil also contains eicosenoic acid (9-eicosenoic acid) in reasonable amounts (9.5–12.4%). The fatty acid composition percentage of Pongamia oil determined by gas chromatography and its physicochemical properties determined as per BIS method are reported in table 1. The Fatty acid composition of Pongamia oil is shown (Table 1).[13].

Table 1	Fatty acid composition of Karanja Oil
Fatty acids	(Wt %)
Palmitic acid	11.65
Srearic acid	7.50
Oleic acid	51.59
Lilonic acid	16.64

Free fatty acid(mgKOHg_1)	5–20

3.EXTRACTION OF PONGAMINA PINNATA OIL :

The extraction of oil from karanja seed was done by using different methods, i.e. mechanical expression, solvent extraction and cold percolation using n-hexane as solvent [14]. As a diesel fuel substitute, Honge falls under the category of bio-diesel. Extraction requires passing the seeds through a screw crusher, generally called expellers. The oil is then filtered to make it clean enough for processing [15]. It is found that the maximum yields were obtained by the Solvent extraction method (31%) as compared to mechanical expeller (24%) and cold percolation method (27%) [16]. Characteristics of fatty acids in karanja oil are as given (Table 2).

Table 2

Sl.no	Fatty Acid	Value (%)
1	Palmitic	3.7 – 7.9
2	Stearic	2.4 – 8.9
3	Oleic	44.5 – 71.3
4	Linoleic	10.8 – 18.3
5	Lignoceric	1.1 – 3.5

Fig.1. Pongamia Tree
Fig.2. Pongamia pinnata seed

3.1EXTRACTION OF LIPIDS FROM M. PINNATA SEEDS :

M. pinnata seeds were first ground to powders with a mortar and pestle and then dried in an oven at 90 °C for 3 days until reaching a constant weight. The powders were then subjected to Soxhlet extraction with hexane for 8 h. After that, the solvent was removed by means of rotary evaporation, and the water present in the oil was further removed by heating in an oven at 90 °C until the sample reached a constant weight. The crude oil content was then estimated as the percentage ratio of the weight of this oil to the weight of the dry powder used for extraction. The resulting oil looks transparent with a yellowish color like normal vegetable oil. A Soxhlet extractor is a piece of laboratory apparatus invented in 1879 by Franz Von Soxhlet. Typically, a Soxhlet extraction is only required where the desired compound has a limited solubility in a solvent, and the impurity is insoluble in that solvent. Normally a solid material containing some of the desired compound is placed inside a thimble made from thick filter paper, which is loaded into the main chamber of the Soxhlet extractor.[17].

Fig.3. Soxhlet Extractor

4.PROPERTIES OF CRUDE PONGAMIA PINNATA OIL :

The large size of the vegetable oil molecules and the presence of oxygen in the molecules suggest that some fuel properties of the vegetable oils would differ markedly from those of hydrocarbon fuels . As we know the fresh extracted crude oil is yellowish red/ brown and it get darkened during the storage. The oil is having disagreeable odor and bitter taste. The solvent extraction method gives good quality oil than ordinary extraction methods. [18]. The iodine value is a measurement of the unsaturation of fats and oils. Higher iodine value indicated that higher unsaturation of fats and oils. Table 4 shows Physico-chemical Properties of Pongamia pinnata -crude oil. Physical-chemical Properties of Pongamia pinnata crude oil given (Table 3).[19].

Table 3

Characteristics	Value
Acid value (mg KOH/g)	5.06
Peroxide number (meq/kg)	7.2
Iodine value(g/100 g)	86.5
Viscosity (40 _C) (mm2/s)	35
Saponification value(mg KOH/g)	187
Unsaponifiable matter(w/w)	2.6

Table 4 : Properties of Pongamia pinnata biodiesel blends

Fuel name	Viscosity 40^{o}C (est)	Density (g/ml)	Calorific value	Cloud point	Flash point	Pour point
Diesel	2.87	0.845	44	6.5	76	3.1
KB100	4.37	0.883	0.883	14.6	163	5.1
KB2	2.90	0.845	43.96	6.6	77.7	3.14

KB5	2.945	0.846	43.90	6.9	80.3	3.2
KB10	3.020	0.846	43.82	7.3	84.7	3.30

5.PROCEDURE FOR PRODUCING THE PONGAMIA PINNATA BIODIESEL :

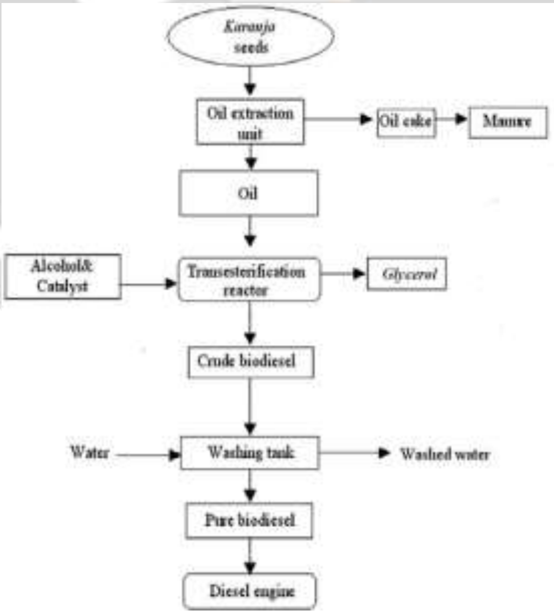
The crude oil of the Pongamia pinnata is first subjected to the Esterification process and then followed by the trans-esterification process. The apparatus used for trans-esterification process is Biodiesel reactor or the Trans-esterification reactor.

5.1ESTERIFICATION

A known amount of Pongamia pinnata oil was taken in the above-mentioned setup. Required amount of sulphuric acid and methanol were added to the oil and stirred continuously maintaining a steady temperature of 64^oC. Intermittently samples were collected at regular intervals (30min) and acid value was determined. After the confirmation of complete reduction of acid valve to less than 1.0, the heating was stopped and the products were cooled. The unreacted methanol was separated by separating funnel.[20][21].

5.2TRANS-ESTERIFICATION :

In the same setup, known amount of esterified Pongamia pinnata oil was charged. Required amount of catalyst NaOH was dissolved in methanol and the rest amount of methanol along with the catalyst solution was added to the oil sample. After proper closing of the flask it was put on the water bath. The system was maintained air tight to prevent the loss of alcohol. The reaction mix was maintained at temperature just above the boiling point of the alcohol i.e. around 70°C to speed up the reaction rate.[22]. Excess alcohol was used to ensure total conversion of the oil to its esters. After the confirmation of completion of methyl ester formation, the heating was stopped and the products were cooled and transferred to a separating funnel. And lower glycerol layer was separated. The oil was then washed several times with hot distilled water until the water didn't turned pink under further addition of phenolphthalein indicator. To the Biodiesel formed anhydrous sodium sulphate was added & left overnight to absorb moisture. The trans-esterification flow process is mention in Flowchart 1 below,.[23].



Flowchart 1

6.PERFORMANCE, EMISSION AND COMBUSTION CHARACTERISTICS OF PONGAMIA PINNATA BIODIESEL :

Performance, emissions and combustion characteristics of Karanja biodiesel blends were evaluated in a typical medium-duty transportation direct injection compression ignition (DICI) engine (Mahindra and Mahindra; MDI 3000) used in a medium size utility vehicle showed on Fig.4.. Test engine was a four-cylinder, four-stroke, variable speed, transportation engine with direct injection of fuel. The technical specifications of the test engine are given in Table 5.[24] The test engine was coupled with an eddy-current dynamometer (Schenck-Avery; ASE-70) for controlling the engine speed and load (Fig. 4). For evaluating the performance, emissions and combustion characteristics of different Karanja biodiesel blends, test engine was suitably instrumented. A laminar flow element (Meriam; 50MC2-2F) was used for intake air flow rate measurement. Volumetric fuel consumption was measured by gravimetric fuel flow meter. The mass of fuel consumed was determined by multiplying volumetric fuel consumption to the density of the test fuel. Concentrations of CO, HC and NOx, in the engine exhaust were measured using raw exhaust gas emission analyzer (Horiba; EXSA-1500). This equipment consists of CO/CO2 analyzer (NDIR detector: MCA 220UA), HC analyzer (Hot flame ionization detector).[25].

Table 5

Technical specifications of the test engine.

Manufacturer/model	Mahindra & Mahindra Ltd., India/MDI 3000
Engine type	Four stroke in-line, Naturally aspirated, Water cooled diesel engine
Number of cylinders	4
Compression ratio	18:1
Combustion system	Direct injection, Re-entrant bowl
Bore/stroke	88.9/101.6 mm
Swept volume	2520 cc
Liner type	Cast iron replaceable wet liners
Fuel injection timing	(SOI) 17 ± 1^{o} BTDC
Injector opening pressure	194 bar
No. of injection holes	4
Rated power	41 kW @ 3000 rpm
Max. torque	152 Nm @ 1800 rpm

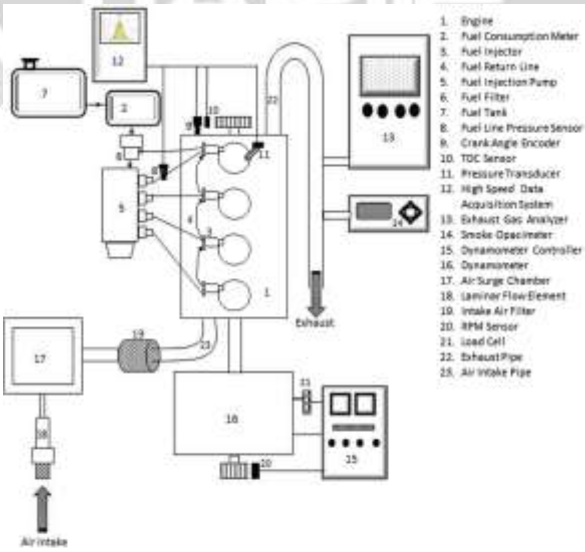


Fig.4. Mahindra DICI Engine

However reduction in torque by 1.4% and 2.1% was observed for higher biodiesel blend (KOME50) and pure biodiesel (KOME100) respectively in comparison to baseline mineral diesel. Table 6 represents the physical properties of test fuels. Sinha et al. also reported slightly higher peak torque for rice-bran biodiesel blends up to B20 and lower torque for B30 and B50 in

Table 6

Important physical properties of test fuels

Test fuel	Viscosity @ 40^{o}c (cst)	Density (g/cm3)	LHV (MJ/kg)
Diesel	2.78	0.831	43.79
KOME 05	2.91	0.833	43.48
KOME 10	3.04	0.836	43.18
KOME 20	3.11	0.841	42.57
KOME 50	3.51	0.856	40.8
KOME 100	4.42	0.881	37.98

comparison to baseline mineral diesel which is represented in Fig.5..[26].Lin et al. reported 3.5% and 1% power reduction for palm biodiesel and B20 at rated load respectively in comparison to baseline mineral diesel.[27].

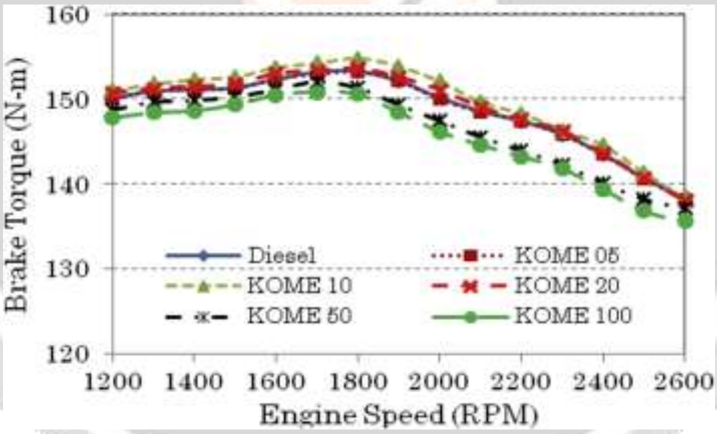


Fig.5. **Speed - torque characteristics of different fuels**

7.RESULTS AND DISCUSSIONS :

7.1 BSFC AND BSEC :

The variation of BSFC and BSEC with load for different blends and diesel are presented in Figs. 8 and 9. It is observed from Figs. 8 and 9 that the BSFC and BSEC for all the fuel blends and diesel tested decrease with increase in load. This is due to higher percentage increase in brake power with load as compared to increase in the fuel consumption. For the blends B20 and B40, the BSFC is lower than and equal to that of diesel, respectively, and the BSEC is less than that of diesel at all loads. This could be due to the presence of dissolved oxygen in the PPME that enables complete combustion and the negative effect of increased viscosity would not have been initiated. However, as the PPME concentration in the blend increases further, the BSFC increases at all loads and the percentage increase is higher at low loads.[28]. In addition, the high viscosity of the blends may also inhibit the proper atomization of the fuel, which in turn affects the combustion process. The Fig.6. shows the variation of bsfc with load for different blends.

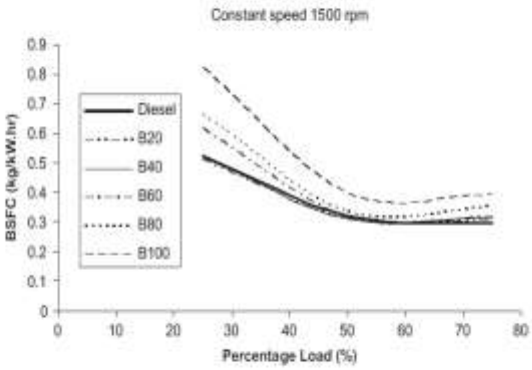


Fig.6. Variation of BSFC with load for different blends.

7.2CO EMISSIONS :

It is interesting to note that the engine emits more CO for diesel as compared to PPME blends under all loading conditions. It is seen from Fig. 10 that the CO concentration is totally absent for the blends of B40 and B60 for all loading conditions and as the PPME concentration in the blend increases above 60%, the presence of CO is observed. At lower PPME concentration, the oxygen present in the PPME aids for complete combustion. However, as the PPME concentration increases, the negative effect due to high viscosity and small increase in specific gravity suppresses the complete combustion process which produces small amount of CO.[29].The Fig.7. shows the Variation of CO emission with load for different blends.

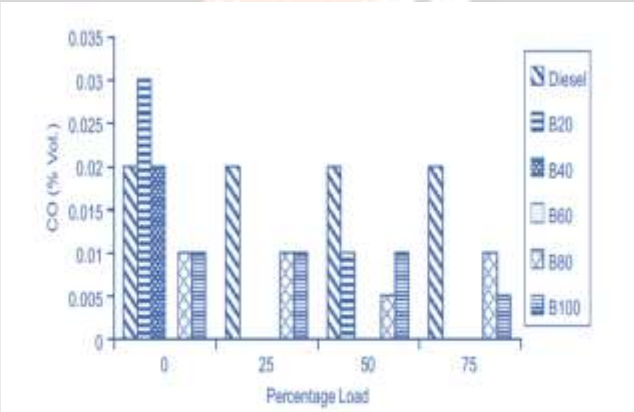


Fig.7. Variation of CO emission with load for different blends.

7.3 CO_2 EMISSIONS :

The CO2 emission increased with increase in load for all blends. The lower percentage of PPME blends emits less amount of CO2 in comparison with diesel. Blends B40 and B60 emit very low emissions. This is due to the fact that biodiesel in general is a low carbon fuel and has a lower elemental carbon to hydrogen ratio than diesel fuel. Using higher content PPME blends, an increase in CO2 emission was noted, which is due to the incomplete combustion as explained earlier. Though at higher loads, higher biodiesel (PPME) content blends emit CO2 almost at par with fossil diesel, in general biodiesels themselves are considered carbon neutral because, all the CO2 released during combustion had been sequestered from the atmosphere for the growth of the vegetable oil crops.[30].The Fig.8. shows Variation of CO_2 emission with load for different blends.

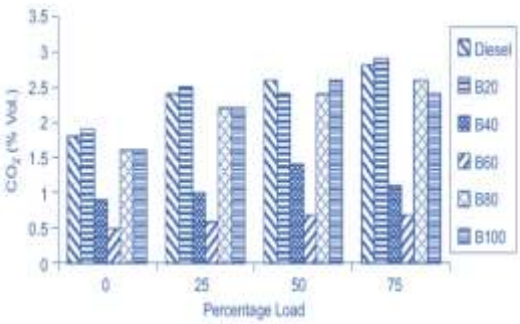


Fig.8. Variation of CO2 emission with load for different blends.

7.4 HC EMISSIONS :

The HC emission variation for different blends is indicated in Fig. 12. It is seen from the figure that the HC emission decreases with increase in load for diesel and it is almost nil for all PPME blends except for B20 where some traces are seen at no load and full load. As the Cetane number of ester based fuel is higher than diesel, it exhibits a shorter delay period and results in better combustion leading to low HC emission. Also the intrinsic oxygen contained by the PPME was responsible for the reduction in HC emission.[31]. The Fig.9. shows Variation of HC emission with load for different blends.

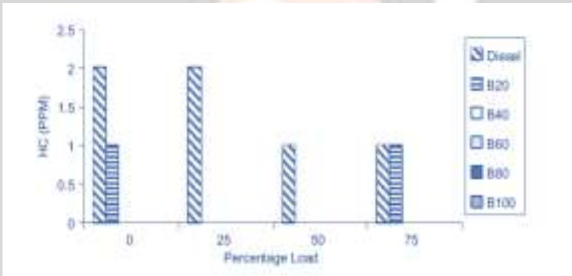


Fig.9. Variation of HC emission with load for different blends

7.5 EXHAUST GAS TEMPERATURE :

The variation of exhaust gas temperature for different blends with respect to the load is indicated in Fig. 10. The exhaust gas temperature for all the fuels tested increases with increase in the load. The amount of fuel injected increases with the engine load in order to maintain the power output and hence the heat release and the exhaust gas temperature rise with increase in load. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber. At all loads, diesel was found to have the highest temperature and the temperatures for the different blends showed a downward trend with increasing concentration of PPME in the blends. This is due to the improved combustion provided by the PPME due to its 11% dissolved oxygen content.[32]. The Fig.10. shows Variation of Exhaust gas temperature with load for different blends.

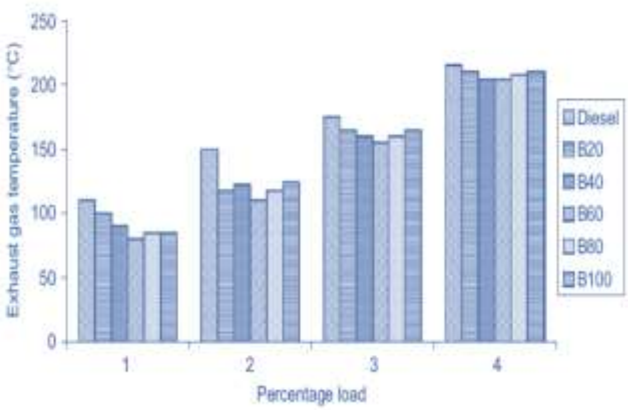


Fig.10. Variation of Exhaust gas temperature with load for different blends.

8.CONCLUSION

Thus this study suggests that the Pongamia pinnata oils can be used as a source of triglycerides in the manufacture of biodiesel by esterification and or trans-esterification. The biodiesel from refined vegetable oils meets the Indian requirements of high speed diesel oil. But the production of biodiesel from edible oil is currently much more expensive than diesel fuels due to relatively high cost of edible oil. There is a need to explore non-edible oils as alternative feed stock for the production of biodiesel non-edible oil like Pongamia pinnata is easily available in many parts of the world including India and it is cheaper compared to edible oils. Production of these oil seeds can be stepped up to use them for production of biodiesel. The production of biodiesel from these oil provides numerous local, regional and national economic benefits. To develop biodiesel into an economically important option in India biotechnological innovations to increase the seed yield are essential. The aim of the present investigation was to analyse the usability of PPME as a replacement to diesel in an unmodified CI engine. It was found that blends of PPME and diesel could be successfully used with acceptable performance and better emissions than pure diesel up to a certain extent. From the experimental investigation, it is concluded that blends of PPME with diesel up to 40% by volume (B40) could replace the diesel for diesel engine applications for getting less emissions and better performance and will thus help in achieving energy economy, environmental protection and rural economic development. In the near future conventional fuels will be fully replaced by biodiesel and will provide a viable solution for the much threatening environmental pollution problems.

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