Performance analysis of karanja and kusum oils as alternative bio-diesel fuel in diesel engine

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Abstract: Scarcity of conventional petroleum resources has promoted research in alternative fuels for internal combustion engines. Among various possible options, fuels derived from triglycerides (vegetable oils/animal fats) are promising for the substitution of fossil diesel fuel. Vegetable oils poses some characteristics like durability, high viscosity and low volatility compared to mineral diesel fuel. In the present work, experiments were designed to study the effect of reducing kusum and karanja oil's viscosity by preheating the fuel, using a shell and tube heat exchanger. The acquired engine data were analyzed for various parameters such as brake thermal efficiency, brake specific energy consumption (BSEC), emission of exhaust gases like CO, CO_2, HC and NO_x. In operation, the engine performance with kusum and karanja oil (preheated), was found to be very close to that of diesel. The preheated oil's performances were found to be slightly inferior in efficiency due to low heating value. The performance of karanja oil was found better than kusum oil in all respects.

Keywords: diesel engine, bio-diesel, kusum oil, karanja oil, alternative fuel, preheating, viscosity, heat exchanger

DOI: 10.3965/j.issn.1934-6344.2011.02.023-028

Citation: Acharya S K, Mishra A K, Rath M, Nayak C. Performance analysis of karanja and kusum oils as alternative bio-diesel fuel in diesel engine. Int J Agric & Biol Eng, 2011; 4(2): 23－28.

1 Introduction

India's demand for diesel fuels is roughly six times that of gasoline hence seeking alternative to mineral diesel is a natural choice[1]. Alternative fuels should be easily available at low cost, be environment friendly and fulfill the energy security needs without sacrificing engine operational performance. For the developing countries, fuels of bio origin provide a feasible solution to the twin crises of fossil fuel depletion and environmental degradation. Now befouls are getting a renewed attention because of global stress on reduction of greenhouse gases and clean environment. The fuels of bio-origin may be alcohol, vegetable oils, biomass and biogas. Some of the fuels can be used directly while others need to be formulated to bring the relevant properties close to conventional fuels[2,3]. Vegetable oils have comparable energy density, cetane number, heat of vaporization, and stoichiometric air/fuel ratio with mineral diesel fuel. In addition, they are biodegradable, non-toxic and have potential to reduce pollution. Contribution of bio-fuels to greenhouse effect is significant, since (CO_2) emitted during combustion is recycled in a photo-synthesis process[4,5]. Use of blends of vegetable oils with diesel has been experimented successfully by various researchers in several countries. It has been reported that 100% vegetable oil is also possible to use in diesel engine with minor fuel system modifications[6]. The use of vegetable oils results in increased volumetric fuel consumption and BSFC[7-9]. However, long term endurance tests reported some engine durability issues related to vegetable oil utilization such as severe engine deposits, piston ring sticking, injector

Received date: 2010-12-07 **Accepted date:** 2011-06-20

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coking, gum formation and lubricating oil thickening[10-12]. In these remote areas, different types of vegetable oils are produced locally but it may not be possible to chemically process them. Hence using heated vegetable oils as petroleum fuel substitutes is an alternative proposition. Keeping these facts in mind, a set of engine experiments were conducted using kusum oil on a C.I engine. The fuel was preheated using exhaust gases, through a shell and tube heat exchanger. This lowered the viscosity of the vegetable oils to tolerable values.

1.1 Karanja oil

Pongamia pinnata is commonly known as karanja in the north and eastern states of India. It is found in the native Western Ghats throughout India, northern Australia, Fiji, and in some regions of eastern Asia. The typical fatty acid composition in oil is shown in Table 1[13]. It grows fast and matures after 4–7 years yielding fruits, which are flat, elliptic and 7.5 cm long as shown in Figure 1. Each fruit contains 1 to 2 kidney shaped brownish red kernels. The oil content of the kernel is 30%–40%. A single tree yields 9–90 kg seed per tree, indicating a yield potential of 900–9 000 kg seed/ha (assuming 100 trees/ha), 25% of which might be rendered as oil. In general, Indian mills extract 24%–27.5% oil, and the village crushers extract 18%–22% oil[14]. The acid value and saponification value of karanja oil have been found to be 5.06 mg KOH/mg, 187 mg KOH/mg respectively. The unsaponifiable matter and iodine value are found to be 2.6(w/w) percent, 86.5(mg/100mg) respectively[13]. The oil is bitter in taste thus it is not considered for edible. The oil is used as a fuel for lamps, as a lubricant, water-paint binder, pesticide and soap making and tanning industries.

Table 1 Characteristics of fatty acids in karanja oil[13]

FA	Value/%
Palmitic	3.7−7.9
Stearic	2.4−8.9
Oleic	44.5−71.3
Linoleic	10.8−18.3
Lignoceric	1.1−3.5
Eicosenoic	9.5−12.4
Arachidic	2.2−4.7
Behenic	4.2−5.3

Figure 1 Karanja tree and seeds (inset)

1.2 Kusum oil

The botanical name of kusum is *Schleichera olcosa* and the potential of kusum oil is 66 000 tonnes per year in India, out of which 4 000 to 5 000 tonnes are collected. It is a medium to large sized, dense tree growing to 35 to 45 feet in height (Figure 2). It mainly occurs in sub-Himalayan tracts in the north, central parts of eastern India. The flowers come from February to April and yields fruit in June and July. The fruits are smooth, hard skin berries contains one or two irregularly ellipsoidal slightly compressed seeds. The brown seed coat is brittle and breaks at a slight pressure to expose a ‘U’ shape kernel. The oil content is 51%–62% but the yields are 25%–27% in village ghanis (oil mills) and about 36% oil in expellers. It contains only 3.6% to 3.9% of glycerin while normal vegetable oil contains 9%–10% glycerine. FFA (Free fatty acid) present in oil is 5%–11%. Iodine value is 215–220 and total fatty acid content is 91.6%. Table 2[14] shows the fatty acid composition of kusum oil. The oil is bitter in taste thus it is not considered to be edible. In India, the oil is used generally for soap making. The oil can be used as substitutes of diesel but the greatest difference between kusum oil and diesel oil is viscosity. The high viscosity of this kusum oil may contribute to the formation of carbon deposits in the engines, incomplete combustion and results in reducing the life of engine. The main objective of present study was to reduce the viscosity of oil by blending with diesel and preheating the kusum oil. Using oil in the above mode performance and exhaust analysis of CI engine was conducted.

Table 2 Characteristics of fatty acids in kusum oil[14]

FA	Value/%
Capric	0.2
Lauric	0.3
Myristic	0.3
Palmitic	8.0
Palmitoleic	1.3
Stearic	2.3
Oleic	42.6
Linoleic	4.5
Arachidic	21.3
Eicosenoic	15.2
Behenic	1.5
Erucic	1.9

Figure 2 Kusum tree and fruit (inset)

2 Materials and methods

The kusum oil and karanja oil used for this study were from the seeds collected from different parts of Orissa and expelled in a mechanical expeller installed in the integrated biodiesel plant of Orissa University Agriculture and Technology, Bhubaneswar, Orissa. Commercially available diesel was purchased from near by IOC petrol tank.

2.1 Extraction of kusum oil

Two methods have been used for extraction of kusum oil from kernel, i.e. the chemical extraction with n-hexane and mechanical extraction method in two stages using screw type of expellers. In the present study, the chemical extraction process gave the oil content about 51% to 53% from the kernel. In the two stages expellers the oil extracted were 30% to 38%.

2.2 Extraction of karanja oil

For extraction of oil from kernel of karanja two methods have been identified. They are the chemical extraction with n-hexane and mechanical extraction method in two stages using screw type of expellers. In the present study, the chemical extraction process gave the oil content about 32% to 33% from the kernel. In the two stages expellers the oil extracted were only 20% to 24%. A mechanical expeller was used as it was already available with the laboratory and it is also cost effective.

2.3 Engine performance test

The typical engine used for stationary application has been selected for present experimental investigation. A single cylinder, four stroke, constant speed, water-cooled, direct injection diesel engine was used for the experiments. The technical specification of the engine is given in Table 3. The engine operated at constant speed of 157 rad/s. The fresh lubricating oil 20W40 was filled in oil sump before starting the experiments. The engine is coupled with single phase 230 V AC alternator with electrical loading. The schematic layout of the experimental set up is shown in Figure 3. The exhaust gas was analyzed by multi-gas analyzer made by NETEL India Pvt. Ltd. The tests were performed in line with ASTM standards as given in Table 4.

Table 3 Engine specifications

Manufacturer:	Kirloskar oil Engine Ltd, India
Engine Type:	Vertical,4 stroke, singl cylinder,constant speed, direct injection, water cooled, compression ignition engine
Rated power:	3.74 kW at 157 rad/s
Piston diameter & stroke length:	0.08 m and 0.11 m
Compression Ratio:	16.5:1

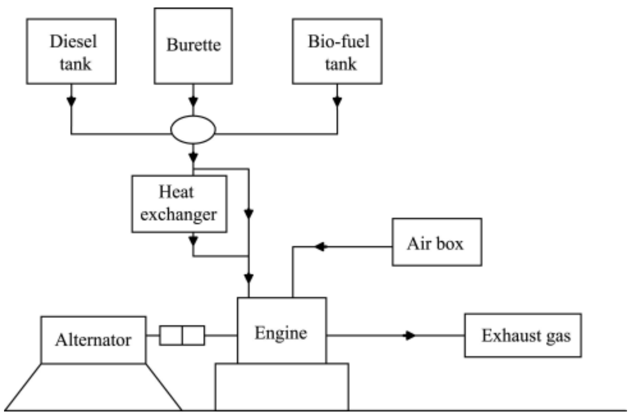

Figure 3 Schematic diagram of experimental setup

Table 4 ASTM methods and instruments use to measure various properties

Property	ASTM method	Instrument
Density	D1298	Hydrometer
Kinetic viscosity	D445	Kinetic Viscometer
Flash Point	D93	Pensky- Martens closed cup tester
Calorific value	D240	Bomb calorimeter

2.4 Heat exchanger

Specifically to avoid the use of external source of energy for preheating oil and to use the waste energy, a heat exchanger is designed according to engine input and output condition. The temperature range maintained using heat exchanger is from 90℃ to 130℃. Variation of viscosity with temperature for karanja and kusum oils was tested and the data is given in Table 5. From this, we can conclude that viscosity of the oils at 100–130℃ is close that of diesel. The detail specifications of the heat exchanger are mentioned in Table 6.

Table 5 Viscosity change with temperature

Temperature/℃	Kinematic viscosity(cSt) Karanja oil	Kinematic viscosity(cSt) Kusum oil
40	28.3	40.00
60	16.2	25.82
80	11.5	16.06
100	6.2	9.40
120	4.2	3.60
130	3.5	

Table 6 Shell and tube heat exchanger specifications

Tube material	Copper
Shell Material	Mild steel
Total tube length	4.5 m
Tube outer diameter	6.5 mm
Tube inner diameter	6 mm
Number of Baffles	04
Number of Pass	15
Shell diameter	150 mm

3 Results and discussion

3.1 Effect of engine load on Brake Specific Energy Consumption (BSEC)

Calorific values of the vegetable oils are lower than diesel. So, for a better basis for comparison, we choose BSEC over brake specific fuel consumption. The results are plotted in Figure 4. It was observed that specific fuel consumption of the preheated oil was higher than diesel. The BSEC of diesel engine depends upon the amount of fuel injected, fuel density, viscosity, heating value and oxygen content. More preheated oil was needed to produce the same amount of energy produced by the pure diesel fuel due to the low heating value of the oil. It was also shown that there is a decrease in BSEC values at high engine loads under all operating modes. It was also found that in comparison to kusum oil, karanja oil is more efficient due to its higher calorific value and lower viscosity (as given in Table 7).

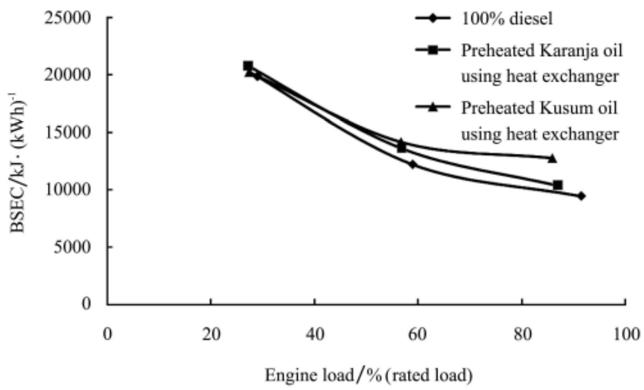

Figure 4 Variation of brake specific engine consumption with engine load

Table 7 Properties of the fuels

Fuel	Sp.gravity	Kinematic viscosity(cSt) at 40/℃	Flash point /℃	Fire point /℃	Calorific value /kJ·kg^{-1}
Diesel oil	0.828	2.90	64	75	43 400
Karanja oil	0.914	28.30	210	219	38 000
Kusum oil	0.904	40.75	147	158	35 000

3.2 Effect of engine load on Brake Thermal Efficiency (BTE)

The variation of brake thermal efficiency of the engine with various fuels is shown in Figure 5. For all the cases, with the increase of engine load, the thermal efficiency increases. The maximum thermal efficiency is achieved at 90% of load of the engine in all modes of operation. The BTE of the vegetable oils was lower than that of diesel throughout the entire range. The drop in thermal efficiency is attributed to the poor combustion characteristics of the vegetable oils due to their high viscosity and poor volatility. It was also found that in comparison to kusum oil, karanja oil is more efficient due to its higher calorific value.

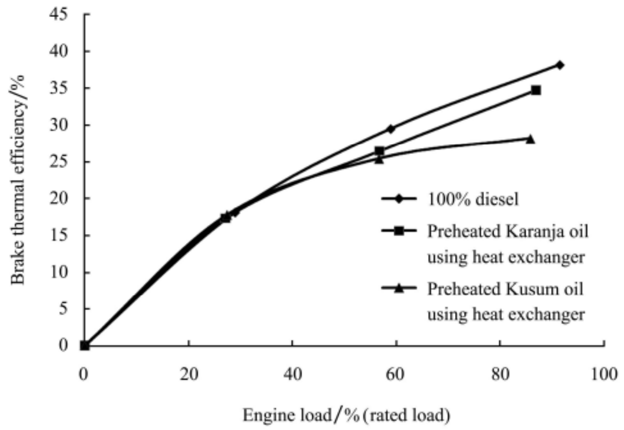

Figure 5 Variation of brake thermal efficiency with engine load

3.3 Effect of exhaust emissions

For preheated oil it was found that much higher composition of CO is present in exhaust gas due to higher viscosity and incomplete combustion shown in Figure 6. For preheated oil, HC composition was found much higher due to high viscosity and atomization problem as shown in Figure 7. The composition of CO_2 was found to be higher as the load increases and the CO_2 composition for vegetable oil is higher due to the oxygenated fuel shown in Figure 8. At low loads, due to incomplete combustion of the more viscous vegetable oils, they produce lesser amounts of CO_2 as compared to diesel. It was also observed that with the increase in load, NO_x composition in exhaust gas increases due to increased combustion temperature of oxygenated fuel, as shown in Figure 9. Smoke composition was found much higher due to high viscosity and incomplete combustion of vegetable oil as shown in Figure 10. Emissions of CO, HC, CO_2, NO_x and smoke using kusum oil were found higher in comparison to karanja oil in all load of operations due to its higher viscosity.

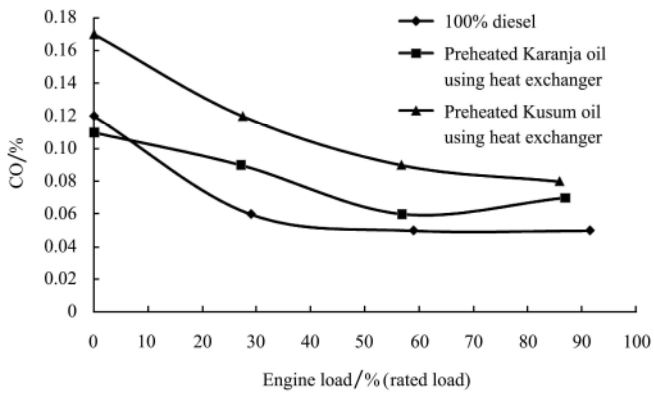

Figure 6 Variation of CO concentration with engine load

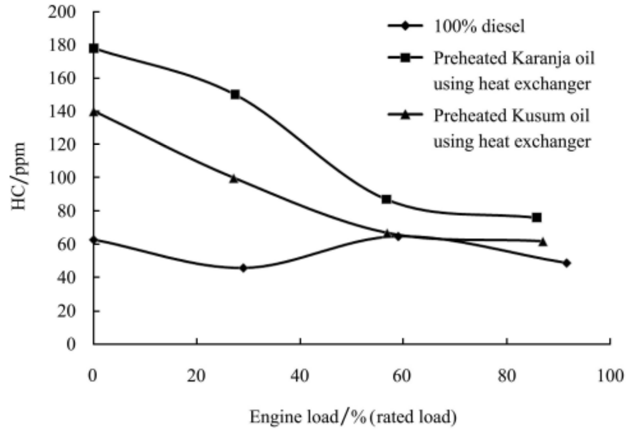

Figure 7 Variation of HC concentration with engine load

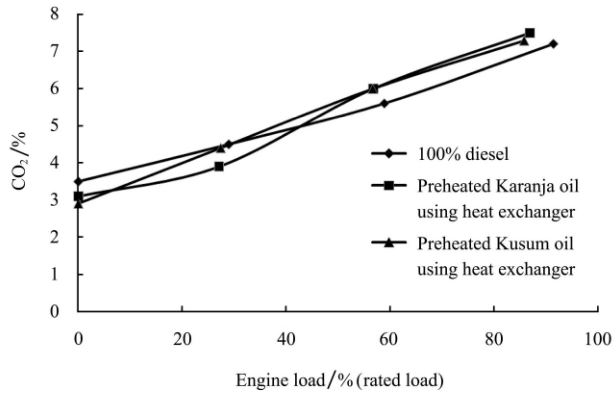

Figure 8 Variation of CO_2 concentration with engine load

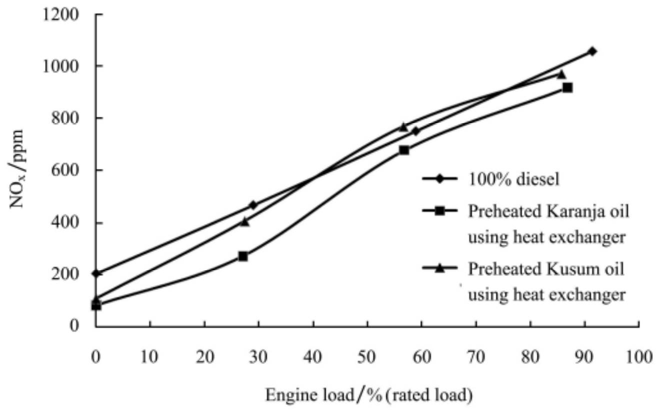

Figure 9 Variation of NO_x concentration with engine load

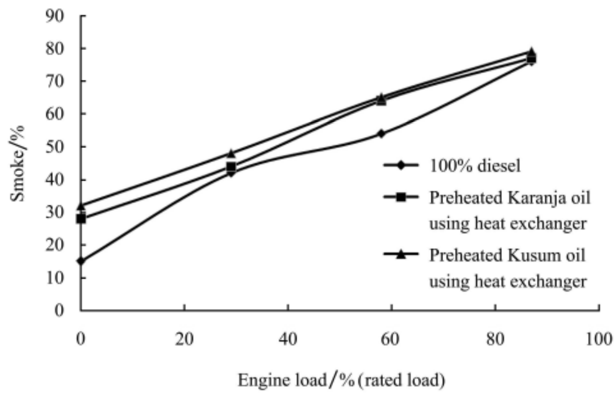

Figure 10 Variation of smoke concentration with engine load

4 Conclusions

The main aim of the present experiment was to use the non edible oil like kusum and karanja oil in stationary diesel engines. We reduced the oil viscosity close to that of diesel without using any external power source and evaluating the performance of engine with the modified oils. The viscosity of kusum and karanja oil was reduced by preheating to 100–130℃. It was found that in the above cases the viscosity was close to that of diesel – which would be suitable for the engines. The performance tests were conducted with diesel, preheated oil at different loads and constant speed of 157 rad/s. From the experimental investigation it was concluded that the performance of kusum and karanja oil in preheated form with specially designed heat exchanger is similar to that of diesel, without any operational difficulties. It is concluded that preheating the oil can be used in diesel engines in rural areas for stationary application like irrigation, processing of agricultural products and electric generation with little voltage drop compared to conventionally fueled engines. In comparison to kusum oil the performance and emission characteristics of karanja oil are better.

Acknowledgements

Authors are very thankful to the Department of Science and Technology, Orissa, India for financial help and necessary steps for setting up experiments at Orissa University of Agriculture and Technology, Bhubaneswar, India.

[References]

[1] Acharya S K, Mohanty M K, Swain R K. Kusum oil as fuel for small horse power diesel engine. International Journal of Engineering and Technology, 2009; 1(3): 219–223.

[2] Acharya S K, Swain R K, Mohanty M K. Performance investigations of karanja oil (Methyl Ester) as fuel in diesel engine with exhaust gas recirculation. International Journal on Mechanical and Automobile Engineering, 2009; 2(2): 87–93.

[3] Agrwal D, Agrwal A K. Performance and emission characteristics of jatropha oil (Pre heated and Blends) in a direct compression ignition engine. Applied Thermal Engineering, 2007; 27: 2314–23.

[4] Agarwal A K, Bijwe J, Das L M. Effect of bio-diesel utilization of wear of vital parts in compression ignition engine. Journal of Engineering for Gas Turbine and Power, 2003; 125: 604–611.

[5] Agarwal A K, Rajamanoharan K. Experimental investigations of performance and emissions of Karanja oil and its blends in a single cylinder agricultural diesel engine. Applied Energy, 2009; 86: 106–112.

[6] Bettis B L, Peterson C L, Auld D L, Driscoll D J, Peterson E D. Fuel characteristics of vegetable oil from oil seed crops in the Pacific Northwest. Agronomy Journal, 1982; 74: 335–39

[7] Crookes R J, Kiannejad F, Nazha M A A. Systematic assessment of combustion characteristics of bio-fuels and emulsions with water for use as diesel engine fuels. Energy Conversion and Management, 1997; 38: 1785–95.

[8] Forson F K, Oduro E K, Hammond D E. Performance of jatropha oil blends in a diesel engine. Renewable Energy, 2004; 29:1135–1145.

[9] Geller D P, Goodrum J W, Campbell C C. Rapid screening of biologically modified vegetable oils for fuel performance. ASAE , 1999; 42(4): 859–62.

[10] Pramanik K. Properties and use of Jatropha curcas oil and diesel fuel blends in compression ignition engine. Renewable Energy, 2003; 28: 239–48.

[11] Ramadhas A S, Jayaraj S, Muraleedharan C. Characterization and effect of using rubber seed oil as fuel in the compression ignition engines. Renewable Energy, 2005; 30: 795–803.

[12] Ramadhas A S, Jayaraj S, Muraleedharan C. Use of vegetable oil as IC engine fuel-a review. Renewable Energy, 2004; 29: 727–742.

[13] Meher L C, Naik S N, Das L M. Methanolysis of Pongamia pinnata (karanja) oil for production of biodiesel. Journal of Scientific and Industrial Research. 2004; 63: 913–918.

[14] Bringi N V. Non traditional oil seeds and in India. New Delhi: Oxford and IBH Publishing Co. Pvt. Ltd. 1980.