Journal of Urban and Environmental Engineering
E-ISSN: 1982-3932
celso@ct.ufpb.br
Universidade Federal da Paraíba
Brasil

Lingfa, Pradip; Das, Biplab
ENERGY ANALYSIS OF KARANJA OIL AS A SUPPLEMENTARY FUEL FOR COMPRESSION IGNITION ENGINE
Journal of Urban and Environmental Engineering, vol. 9, núm. 2, 2015, pp. 97-101
Universidade Federal da Paraíba
Paraíba, Brasil

Journal of Urban and Environmental Engineering, v.9, n.2, p.97-101

ISSN 1982-3932
doi: 10.4090/juee.2015.v9n2.097101

Journal of Urban and Environmental Engineering

www.journal-uee.org

ENERGY ANALYSIS OF KARANJA OIL AS A SUPPLEMENTARY FUEL FOR COMPRESSION IGNITION ENGINE

Pradip Lingfa* and Biplab Das

Department of Mechanical Engineering, North Eastern Regional Institute of Science and Technology, India

Received 7 March 2014; received in revised form 19 September 2015; accepted 21 September 2015

Abstract: The paper highlights the results of an experimental investigation carried out on Karanja oil as a supplementary for diesel fuel in Compression Ignition engine. In the present study, triglycerides of Karanja oil is converted into mono-ester (biodiesel) using based catalyst transesterfication process. Karanja biodiesel is blended with petroleum diesel in the volumetric proportions of 2−10%. Results reveal that the performance characteristics of Karanja biodiesel blends are well comparable with diesel fuel. The emission characteristics such as CO, HC and smoke are found to be lower for Karanja biodiesel blends at all the engine load conditions compared to diesel fuel. Hence, it is concluded that Karanja oil at lower blends can be used in diesel engine without any substantial engine modification.

Keywords: Karanja; transesetrification; BSFC; emission

* Correspondence to: Pradip Lingfa, Tel.: +91 9774 516964; Fax: +91 360 2257433. E-mail: plingfa@yahoo.com

INTRODUCTION

In view of the escalating energy (fuel) crisis and environmental pollution, non-edible vegetable oil is one of the promising sources for replacement of petro-diesel, thereby reducing country's dependence on importing petroleum from the overseas country. The concept of producing liquid fuel for diesel engine is not radically new concept. When Rudolf Diesel first invented the diesel engine, about a century ago, he demonstrated the principle by employing peanut oil (Debnath *et al*., 2013).

In view of the potential properties of vegetable oils, various countries carried out many experimental works using edible and non–edible vegetable oils as a diesel substitute (Barma *et al*., 2011). The most prominently are Sunflower, Safflower, Soybean, Cotton seed, Canola and Peanut oil, *Jatropha* and *Pongamia Pinnata* etc. However, most of these oils are edible in nature hence expensive in developing countries. Therefore, the stresses are on non- edible vegetable oils such as Rubber seeds, Linseeds, Mahua, Sunflower, Soameruba, Pine, Sal, *Messua ferra*, and Tung fruit (Kannan and Anand, 2012; Lingfa *et al*., 2012).

In the present study, non-edible vegetable oil from Karanja seed has been studied. From the pertinent literaure, it was observed that the performance and emisions studies in diesel engine using Karanja biodiesel especially at lower blends of biodiesel with high speed diesel have scantly been reported.

Karanja (*Pongamia pinnata*) belongs to family of Leguminaceae. It is a medium sized tree that attains a height of about 18m and a trunk diameter greater than 50 cm. The fresh extracted oil is yellowish orange to brown and rapidly darkens on storage. It requires no care and can be grown in the wasted lands. Karanja oil contains several furanoflavones such as, karanjin, pongapin, kanjone and pongaglabrin. This oil is used as an ointment for rheumatism. Juice of leaves is also used for colds, coughs, diarrhea (Baiju *et al*., 2009; Sahoo *et al*., 2009).

Studies on the performance of Karanja oil as an alternative fuel for CI engine may be seen on (Baiju *et al*., 2009; Sahoo *et al*., 2009). Baiju *et al*. (2009) have performed the experimental studies using an oil blend Karanja methyl ester and ethyl ester of 20% and 100%. Later Sahoo *et al*. (2009) performed the experimental tests with blend of 20%, 50% and 100% with diesel. Replacement of petroleum diesel fuel with natural biodiesel is always welcome, but use of higher blend in low temperature of region like Arunachal Pradesh, India, may not be suggestive as higher percentage of biodiesel may will cause in higher pour and cloud point.

The present studies were carried out with aim to understand the effect of various biodiesel bends obtained from Karanja oil at lower blend of diesel and biodiesel. The performance and emissions part were analyzed to ensure minimum power drop and emission remained within the limits. The oxygenated nature of biodiesel tends to improve the combustion efficiency at the same time it is also a factor contributing to increase of NOx. The experiments helped in determining the optimum biodiesel blend suitable for operation in an unmodified stationary diesel engine. Details of the materials and methods are presented in the following subsection.

MATERIALS AND METHODS

Potassium hydroxide and alcohol such as methanol were used to Transesterification process. Karanja seeds were procured from Kadalaf oil mill Sangola (Maharashtra). The extraction of oil was carried out using mechanical oil expeller available at biodiesel centre of North Eastern Regional Institute of Science & Technology, Itanagar Arunachal Pradesh (India).

Test procedure

Production of biodiesel

The Karanja biodiesel was produced using based catalyst transesterification process in the laboratory. The laboratory set up consists of heating mantle, reaction flask and mechanical stirrer (**Fig. 1**). It consists of three necks for stirrer, condenser and inlet for reactant as well as for placing the thermocouple to observe the reaction temperature. The flask has a stopcock at the bottom for collection of the final product. Initially the required amount of raw oils, alcohol and catalyst were added to the reactor. The mixtures were allowed to react for 2–3 hours. After the completion of reaction, the mixture mainly consisted of two products, namely, biodiesel and glycerol. After removing the glycerol layer using separating funnel, the methyl ester was water washed using distilled hot water. After water-washing the methyl ester was heated in an oven to remove the traces of water. A detail of the production procedure (seed to oil) is shown in **Fig. 2**.

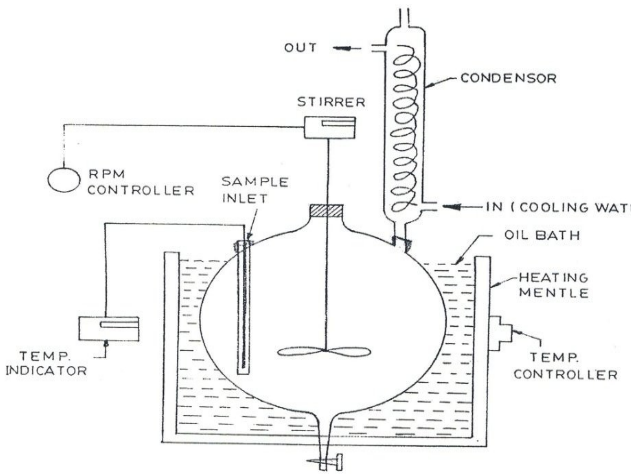

Fig. 1 Schematic diagram for transesterification reactor.

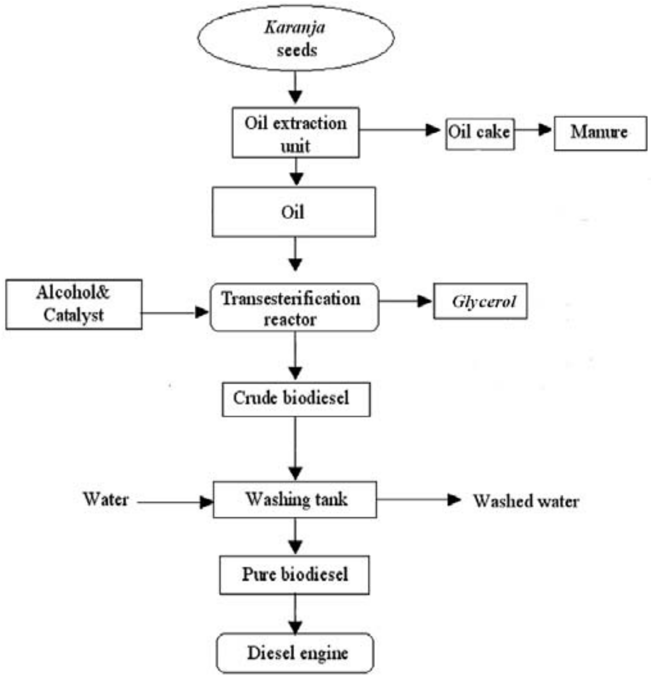

Fig. 2 The process flowchart for biodiesel production.

Engine test

As crux of the paper is to study CI engine performance and keeping in view of the specific features of diesel engine in mind, a typical engine which is used widely in the Indian agricultural sector, has been selected for the present experimental investigations (**Fig. 3**). A Kirlosker made single cylinder, air cooled, direct injection, TAF1 model diesel engine is used for present study (**Table 1**). The engine is coupled to a 5 kVA electric generator through which load has been applied by increasing the voltage. Tests are carried out over entire range of engine operation at constant speed of 1500 rpm under varying load conditions. The emission characteristics are measured using AVL Di-gas analyzer and AVL 437 Smoke meter.

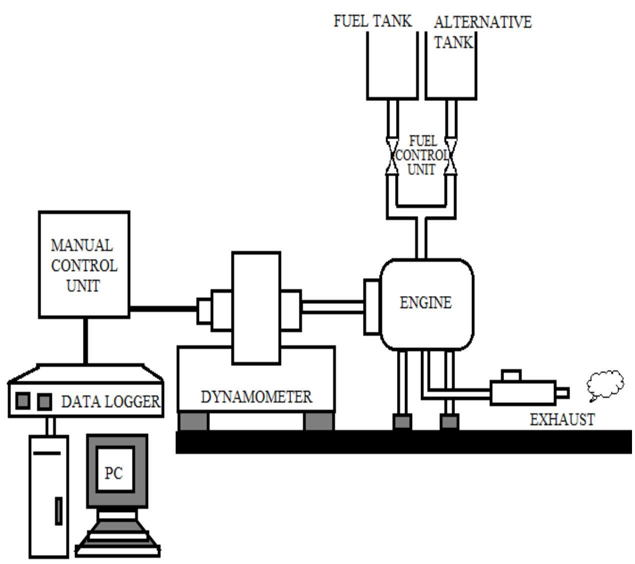

Fig. 3 Schematic diagram of experimental setup for engine test rig.

Table 1. Technical specifications of test engine

Engine	
Make	Kirlosker Ltd
Model	TAF1
No. of cylinder	1
Cycle	4 stroke
Bore	87.5 mm
Stroke	110 mm
Displacement volume	662 cm^3
Compression ratio	17.5:1
Rated power (@1500 RPM)	4.4/6 (kW/BHP)
Injection Timing	23° BTDC
Inlet valve opens BTDC	4.5°
Inlet valve closes ABDC	35.5°
Exhaust valve opens BBDC	35.5°
Exhaust valve closes ATDC	4.5°

Table 2. Properties of Karanja biodiesel blends

Fuel name	Viscosity 40°C (cst)	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	42.133	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

RESULTS AND DISCUSSION

Production and characterization of Karanja methyl ester (KOME). The methyl esters of Karanja oil is produced using bases catalyst transesterification process. The reaction parameters such as molar ratio, reaction time, temperature and stirring speed are varied to obtain maximum yields of methyl ester. The properties of characterized fuels are as shown in **Table 2**. Biodiesel and diesel are blended at different volumetric ratio and named as KB, e.g., KB2 stands for 2% Karanaja oil and 98% diesel by volume in the blend. In the blends volumetric fraction of Karanja oil ranges from 0 to 10%. By comparing the density and viscosity of KB100 (100% biodiesel) with KB0 (100% diesel), it is seen that, viscosity and density of the blends increases with increase in volumetric fraction of Karanja oil in the blends.

This limits the direct use of neat biodiesel (B100) in the engine especially in the lower temperature regions. A apart from density and viscosity of blend B0, higher value of pour and cloud point is also observed for higher percentage of Karanja oil in the blend. Lower calorific value is also observed for higher percentage of oil in the blend. All these cumulative factors This may cause injector coking, severe engine deposits, filter gumming, piston ring sticking and thickening of lubrication oil and host of other problems, restricting the use of higher percentage of biodiesel-diesel blend. With the rapid decrease in stock of petroleum diesel and exponentially increase in demand for the same, pushes the researchers to find the possibility of alternative fuel and their performance with lower as well as higher percentage of biodiesel bend. In this study an attempt is made to use the lower percentage of biodiesel diesel blend as an alternative fuel for IC engine. The engine performance and emission characteristics of different oil blends are discussed in the following subsection.

Performance and emission of Karanja methyl ester

Figure 4 shows the comparison of brake thermal efficiency (BTE) for diesel fuel and Karanja biodiesel blends at different loads. It is observed that BTE increases with increasing loads for the engine fueled with Karanja biodiesel and its blends. This could be due to the presence of oxygen (10-11%) in fuel itself which helps in complete combustion. Further, comparing the performance of all the biodiesel blends it can be seen that KB10 (10% Karanja biodiesel and 90% diesel) shows highest BTE among the all biodiesel blends.

Figure 5 shows the variation of brake specific fuel consumptions (BSFC) for different biodiesel blends. It is revealed that BSFC of all the fuel decreases with increase in loads and it increases with increase in biodiesel blends. It may be pointed out that as the calorific value of biodiesel is lesser than that of the commercial diesel, an increase in BSFC is observed.

Figure 6 revels the emission of exhaust gas performance at different loads. It is seen that at lower loads, variation for CO emissions for biodiesel and its blends is insignificant. It is also observed that at higher load it increases for all test fuels. This may be due to the fact that air fuel mixing was affected by difficulty in atomization of heavy compounds. The resulting locally rich mixture resulting in incomplete combustion causes more CO to be produced during combustion due to lack of sufficient oxygen, it is also observed by earlier investigator (Baiju *et al.*, 2009; Dattatray and Joshi, 2011). From the graph, it is further observed that KB10 emits the least CO, due to enrichment of oxygen owing to biodiesel addition, which results in better combustion.

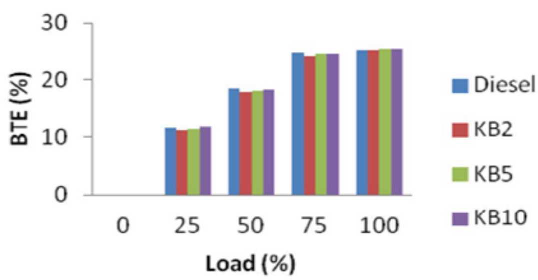

Fig. 4 Variation of loads with BTE.

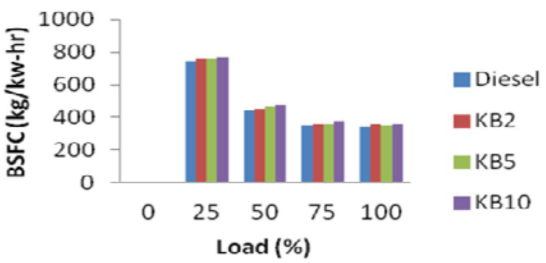

Fig. 5 Variation of loads with BSFC.

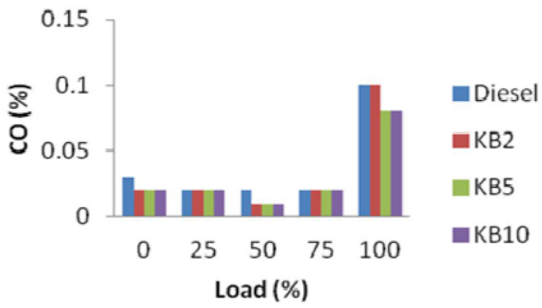

Fig. 6 Variation of loads with CO

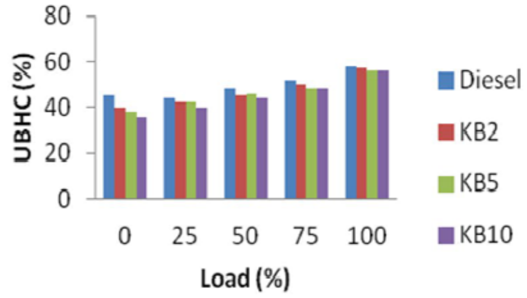

Fig. 7 Variation of loads with UBHC.

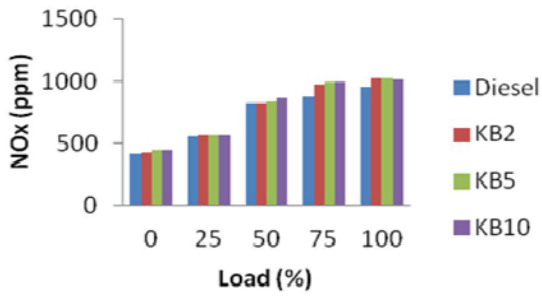

Fig. 8 Variation of loads with NOx.

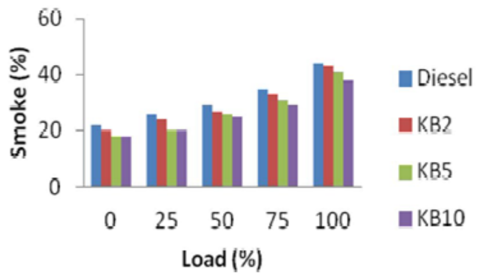

Fig. 9 Variation of loads with smoke.

Figure 7 shows the comparison of unburned hydrocarbon (UBHC) for diesel, biodiesel and its blends at different loads. The UBHC of all the test fuels increases at higher load, due to the fact that fuel quantity injected is increased hereby contributing to increases in HC emissions. It is also observed that minimum UBHC was achieved with KB10 due to more oxygen content owing to better combustion.

Figure 8 represents the NOx emission at different loads and for different blends of biodiesel and diesel. It is observed that NOx emission increases with increase in loads. This is probably due to formation of higher combustion chamber temperature, and presence of oxygen concentration in the mixture of biodiesel and its blends, which is an agreement with the earlier investigation (Baiju *et al*., 2009; Dattatray and Joshi, 2011). This is obvious since more fuel is supplied at large loads and less time is available for preparation of air-fuel mixture. Moreover, due to higher bulk modulus of biodiesel there is advancement of injection timing caused by the rapid transfer of pressure wave from the fuel injection pump to the fuel injector causing the fuel injector to open earlier and thus effect the NOx emissions.

Variation of smoke levels for different methyl easter are presented in **Fig. 9**. From the figure it is seen that the smoke levels of methyl ester and their blends are significantly lower than that of diesel fuel. These improvements of smoke emissions may be probably due to the oxygen content in biodiesel which helps in better combustion than diesel fuel. Since smoke is produced mainly in the diffusion combustion phase, the addition of oxygenated fuel leads to an improvement in diffusion combustion phase. It is also observed that with increase in biodiesel addition (blends) to diesel the smoke emissions reduces compared to diesel fuel.

CONCLUSIONS

In the present study, triglycerides of Karanja oil was converted to mono-esters using catalyst transesterification process. The kinematic viscosity of Karanja oil reduced significantly after transesterification process. Higher value of cloud and pour point restrict the use of higher blend of Karanja oil and diesel in low temperature zone. The BTE of Karanja biodiesel are lower than that of diesel fuel. The BSFC of biodiesel blends decreases at increasing loads but further increased of concentration of biodiesel blends increased the fuel consumptions due to lower calorific value and higher viscosity. The emission characteristics like CO, HC, and smoke were observed to be lower than diesel fuel. However NOx emission was higher for biodiesel blends. Among the various blends studied it was found that 10% blend of Karanja yields the best result in terms of performance and emission. Upto75% of loading is more suitable both performance and emission point of view.

Acknowledgement The authors sincerely acknowledge financial support of Department of Science and Technology (India), and the Biodiesel Centre of NERIST, India.

REFERENCES

Baiju, B., Naik, M.K., Das, L.M. (2009) A comparative evaluation of compression ignition engine characteristics using methyl and ethyl esters of Karanja oil. *Renew. Ener.,* **34**, 1616–1621.

Barma, S.D., Das, B., Giri, A., Majumder, S., Bose, P.K. (2011) Back propagation artificial neural network (BPANN) based performance analysis of diesel engine using biodiesel. *J. Renew. Sustain. Ener.,* **3**, 013101-11.

Canakci, M. (2007) Combustion characteristics of a turbocharged DI compression ignition engine fuelled with petroleum diesel fuels and biodiesel. Bioresource Technology, 98:1167– 1175.

Dattatray, H.B. & Joshi S.V. (2011) Performance, emission and combustion characteristics of a multi-cylinder DI diesel engine-ethanol-biodiesel blends of high ethanol content. *Appl. Ener.* **88**, 5042-5055.

Debnath, B.K., Sahoo, N., Saha, U.K. (2013) "Adjusting the operating characteristics to improve the performance of an emulsified palm oil methyl ester run diesel engine". *Energy Conver. Manag.*, **69**(2), 191–198.

Kannan, G.R. and Anand, R. (2012) Biodiesel as an alternative fuel for direct injection diesel engines: A review. *J. Renew. Sustain. Ener.,* **4**, 012703

Komariah, L.N., Arita, S., Novia, S., Wirawan, S., Yazid, M. (2013) Emission factors of biodiesel combustion in industrial boiler: A comparison to fossil fuel. *J. Renew. Sustain. Ener.*, **5**, 052005.

Lingfa, P., Prasad L., Mahendru, K., Das, L.M., Naik, S.N. (2012) Current status of non–edible vegetable oil-based biodiesel as an alternative fuel for diesel engine: Indian Perspectives. *Int. J. Engin. Sci.,* **3**, 554-558.

Panday, K.C., Panday, K.P., Ghosh, B.B. (2007) Critical review on vegetable oils as Substitute's fuel for diesel engine. *Proc. of the XVI National Conference on I.C. Engines and Combustion*. 6: 95-104.

Sahoo, P.K., Das, L.M., Babu, M.K.G., Arora, P., Singh, V.P. Kumar, N.R., Varyani, T.S. (2009) Comparative evaluation of performance and emission characteristics of Jatropha, Karanja and Polanga based biodiesel as fuel in a tractor engine. *Fuel*, **88**, 1698–1707.

Sharma, A. (2008) Biodiesel: An eco-friendly fuel. *Asian Sci.*, **1-2**,1-3.