International Journal of Ambient Energy

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/taen20

An analysis of rice-bran oil as a biofuel for the four-stroke, twin-cylinder CI engine

I. Vinoth Kanna, R. Tamil Selvan & D. Pinky

INTERNATIONAL JOURNAL OF AMBIENT ENERGY
2021, VOL. 42, NO. 3, 319–324
https://doi.org/10.1080/01430750.2018.1550015

An analysis of rice-bran oil as a biofuel for the four-stroke, twin-cylinder CI engine

I. Vinoth Kanna [a], R. Tamil Selvan [b] and D. Pinky [c]

[a]Department of Mechanical Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, India; [b]Department of Mechanical Engineering, Mahendra Engineering College (Autonomous), Namakkal, India; [c]Department of Mechatronics Engineering, Agni College of Technology, Chennai

ABSTRACT
Petroleum product has seen a drastic demand in the recent past. In this scenario it is important to come up with alternate fuels with better efficiency. This experimental study was undertaken to investigate the use of a blend of rice bran oil and ethanol with various propositions as a substitute to diesel fuel. Its performance charactertics are analysed in a diesel engine and are reported. We are also dealing with a solution to avoid gel formation in cold condition. Emission of CO and NO*x* is prevented by a three-way catalytic converter. Experimental investigations were carried out on a four-stroke, twin-cylinder CI diesel engine. Various blends of biodiesel (rice bran ethyl ester) and ethanol ranging from 5% to 15% in the blend were used.

ARTICLE HISTORY
Received 16 August 2018
Accepted 13 November 2018

KEYWORDS
Biofuel; rice bran oil; ethanol; gel forming; catalytic convertor

1. Introduction

The industrialisation and motorisation of the world led to a steep rise in the demand for petroleum products. Petroleum-based fuels are depleting continuously as they are non-renewable energy sources (Inoue and Noguchi 1964; Saravanan, Nagarajan, and Lakshmi Narayana Rao 2008). In this paper we have discussed about alternate sources of fuel for automobiles. Generation of the alternate sources mainly depends on waste rice husk for the production of rice bran oil (Bakota et al. 2013; Parthiban and Perumalsamy 2016). The rice bran oil is converted into ester by the process of trans-esterification. Emission of CO and NO*x* is prevented by a three –way catalytic converter (Narayan, Barhate, and Raghavarao 2006; Hua et al. 2016; Vinoth kanna and Pinky 2018c). Experimental investigations were carried out on a four-stroke, twin-cylinder compression ignition (CI) diesel engine. Its performance charactertics are compared with diesel and plotted. By-product glycerin is obtained during trans-esterification and used for other useful purposes like cosmetics.

2. Biofuel

Biofuel is an alternate for diesel in the combustion ignition engine. Biofuel are obtained from oil containing high fatty acids by the process of trans-esterification (Mishra, Sharma, and Sengar 2012; Parthiban and Perumalsamy 2016; Devaraj, Yuvarajan, and Vinoth Kanna 2018). Various biofuels used are vegetable oil, castor oil, canola oil, rice bran oil, etc. Rice bran oil is chosen as biofuel because of its mass availability in the sub-continent and cheaper in terms of cost (Vinoth kanna 2018; Vinoth Kanna, Devaraj, and Subramani 2018a; Vinoth Kanna, Vasudevan, and Subramani 2018b).

3. Physical properties of rice bran oil

Crude rice bran oil (CRBO) with high free fatty acid (FFA) content is not suitable for cooking purposes, however, it can be used as a fuel to partially replace or fully replace diesel (Saravanan, Nagarajan, and Lakshmi Narayana Rao 2008; Jongjareonrak et al. 2015; Ponchurdchai and Singkhonrat 2016; Vinoth Kanna and Pinky 2018b). Rice bran oil contains a range of fats, with 47% of its fats being monounsaturated, 33% polyunsaturated, and 20% saturated. It was observed that the viscosity of the blends increased with an increase in free fatty acid (FFA) (Lakkakula, Lima, and Walker 2004; Saravanan, Nagarajan, and Lakshmi Narayana Rao 2008; Prichapan, McClements, and Klinkesorn 2017; Nagappan and Vinoth Kanna 2018; Vinoth Kanna and Paturu 2018) while the calorific value decreased. Significant variations were observed in the distillation curve for the CRBO blends with different FFAs. Aniline point of the blends was 10–15% lower than that of diesel (Kumar Sharma et al. 2006; Narayan, Barhate, and Raghavarao 2006; Saravanan, Nagarajan, and Lakshmi Narayana Rao 2008; Kumar, Iruthayarajan, and Bakrutheen 2016; Vinoth Kanna, Vasudevan, and Subramani 2018b) and it is indirectly proportional to the FFA of CRBO in the blend. Experimental results showed that the combustion properties of CRBO are the function of the FFA in the oil (Park, Choi, and Han 2008; Rani 2017; Vinoth Kanna and Paturu 2018; Vinoth kanna and Pinky 2018a). As a dilute blend with diesel, CRBO with high FFA content showed comparable combustion properties to that of diesel. The properties differed in magnitude by 10–15% when compared with diesel (Saravanan, Nagarajan, and Lakshmi Narayana Rao 2008; Guo and Aryana 2016). From the present investigation it is concluded that in a blended form, CRBO with high FFA can be a potential resource to utilise it as an alternative fuel for CI engines (Saravanan, Nagarajan, and Lakshmi Narayana

CONTACT I. Vinoth Kanna vinothkanna.research@gmail.com

Rao 2008; Utarwuthipong et al. 2009; Sayasoonthorn, Kaewrueng, and Patharasathapornkul 2012; Nakajima et al. 2017; Pal and Pratap 2017).

4. Method for reducing the viscosity

Heating the rice bran oil to sufficient temperatures is to lower the viscosity to near specification range. This method involves some practical difficulties and increases the cost of the fuel (Saravanan, Nagarajan, and Lakshmi Narayana Rao 2008; Ponchurdchai and Singkhonrat 2016; Reyhanitash et al. 2016; Vinoth kanna 2018; Vinoth kanna and Pinky 2018c).

Diluting the rice bran oil by mixing with other less viscous liquid fuels forms blends. But the mixture of rice bran oil and ethanol is not a stable mixture because instead of forming a homogeneous mixture, two layers are formed (Saravanan, Nagarajan, and Lakshmi Narayana Rao 2008; Saydut et al. 2016; Rani 2017; Paturu and Vinoth kanna 2018). Therefore, the stability of the mixture must be increased. The rice bran oil may be converted into simple esters of methyl, ethyl or butyl alcohols (Saravanan, Nagarajan, and Lakshmi Narayana Rao 2008).

5. Feed stock for bio diesel

Rice bran oil is a non-conventional, inexpensive and low-grade vegetable oil. Crude rice bran oil is also a source of high value added by-products. Thus, if the by-products are derived from the crude rice bran oil and the resultant oil is used as a feedstock for biodiesel, the resulting biodiesel could be quite economical and affordable (Bio diesel Technologies in India).

6. Fatty acid ethyl esters from rice bran oil

Fatty acids esters are known to be good alternative fuels (biodiesel). Due to economic reasons, the use of cheap materials as substrates for biodiesel is being preferred. In this case, rice bran oil, which cannot be considered as an edible oil, is an interesting substrate. Esterification of high-acidity rice bran oil with ethanol and sulphuric acid catalyst was investigated. The effects of FFA contents of rice bran oil and ethanol concentration on in situ esterification were investigated and compositions of produced ethyl esters due to the conditions were determined (Bio Diesel Technologies in India).

7. Acid-catalysed trans-esterification of rice bran oil for bio diesel production

The high value of soybean oil or canola oil as a food product makes the production of a cost-effective fuel very challenging. The use of edible oils as biodiesel feedstock cost about 60–70% of raw material cost. Non-edible, inexpensive, low-grade oils with value added by-products is utmost important to make the biodiesel production economical. Rice bran oil ranks first among the non-conventional, inexpensive, low-grade vegetable oils. Furthermore, crude rice bran oil is a rich source of high value-added by-product. Therefore, the use of rice bran oil as the raw material for the production of biodiesel not only makes the process economical but also generates value-added bio-active compounds. Isolation and purification of these by-products make the process attractive and remunerative. In the present investigation a systematic study of trans-esterification of high FFA rice bran oil was carried out to establish the optimal reaction condition. It was found that acid-catalysed methanolysis of fatty acids is faster than pure triglycerides or pure triglycerides plus 5% water. More than 99% of FA were converted to their corresponding FAME with 20 min of reaction times at the temperature of boiling point of methanol otherwise almost for 6 h reaction none of TG was converted. The effect of chain length and unsaturation of fatty acid on the rate of esterification of fatty acid with methanol are equally reactive irrespective of differences in their chemical structures. Fatty acids from different sources show similar conversions and change in the fatty acids composition has no effect on the rate of methanolysis (Bio Diesel Technologies in India).

Table 1. Fatty acid percentage (Bio diesel Technologies in India).

Palmitic	15.0%
Stearic	1.9%
Oleic	42.5%
Linoleic	39.1%
Linolenic	1.1%
Arachidic	0.5%
Behenic	0.2%

Rice bran oil is the oil extracted from the germ and the inner husk of rice. It is notable for its very high smoke point of 490°F (254°C) and its mild flavour, making it suitable for high-temperature cooking methods such as stir frying and deep frying. It is popular as cooking oil in several Asian countries, including Japan and China.

Rice bran oil contains a range of fats, with 47% of its fats monounsaturated, 33% polyunsaturated and 20% saturated. The fatty acid composition of rice bran oil is given in Table 1:

8. Trans-esterification of rice bran oil

Biodiesel is methyl or ethyl ester of fatty acid made from rice bran oils and animal fats. The main commodity sources for biodiesel in India can be non-edible oils obtained from plant species (Fadhil, Aziz, and Altamer 2016; Vinoth kanna and Pinky 2018c). Biodiesel contains no petroleum, but it can blend at any level with petroleum diesel to create a biodiesel blend or can be used in the pure form (Devaraj, Yuvarajan, and Vinoth Kanna 2018). Just like petroleum diesel, biodiesel operates in the CI engine, which essentially requires very little or no engine modifications because biodiesel has properties similar to petroleum diesel fuels. It can be stored just like the petroleum diesel fuel and hence does not require a separate infrastructure (Fadhil, Aziz, and Altamer 2016; Anon 2017).

9. Trans-esterification processes

There are different types of trans-esterification like batch process, acid catalyst direct esterification, Biox process and plug in flow reaction process. We have discussed the acid catalyst direct esterification process (Vinoth kanna 2018b).

10. Process

The rice bran oil was initially filtered to remove impurities and any foreign materials. One litre of rice bran oil is measured and

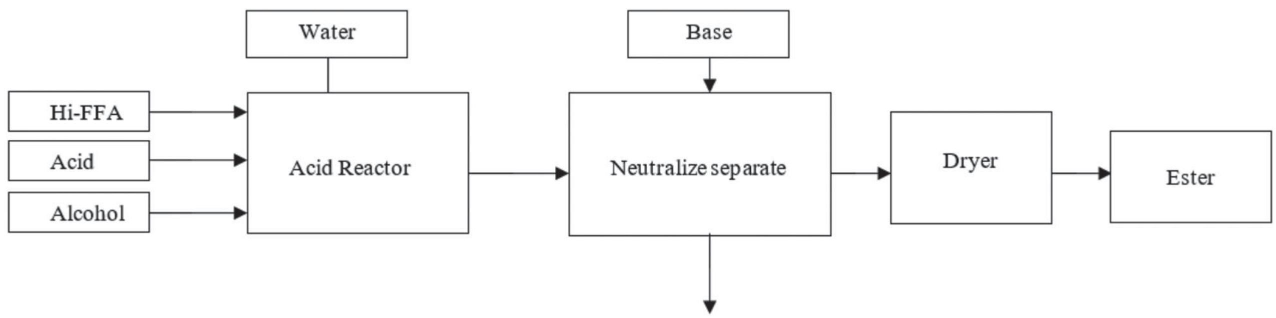

Figure 1. Acid catalyst direct trans-esterification.

taken in the two litre flask with round bottom flask. It was then kept on the heating mantle and heated up to 100˚C to remove water particles present in it. It is done for two and half hours. Then the oil is cooled to 35˚C, followed by the addition of 80 mL of methanol to the oil at 35˚C and stirred for 5 min. One millilitre of H_2SO_4 is added to the oil at 35˚C and stirred for one hour. Then it is allowed to settle for eight hours. The methoxide solution was prepared by adding 3.5 g of NaOH pellets to 120 mL of methanol in a small beaker. Entire NaOH pellets were completely dissolved in methanol. Fifty per cent of the above methoxide solution was measured and added to the oil in the flask and stirred for 5 min. Now the entire contents were heated to 55˚C. Remaining 50% of methoxide solutions were added to the oil at 55˚C and stirred for 1.5–2.5 h maintaining the temperature at 55˚C. The heater was switched off and the oil was cooled down to room temperature. The oil was allowed to settle for one hour to separate glycerol from the oil (Biodiesel) (Figure 1).

11. Comparison of production cost with other produced biodiesel

From Table 2, it can be easily noted that the production cost of biodiesel from rice bran oil compared with that of jatropha, neem, and castor oil is very low. At the same time, the production cost of biodiesel from rice bran oil is close to that of sunflower and coconut oil. So we can conclude by saying that with respect to the production cost, rice bran has the prospect for producing biodiesel (Wakil et al. 2016).

12. Effect on combustion properties

Combustion properties of the ester blend of rice bran oil and ethanol is analysed in the CI [Lister engine] of a twin-cylinder four-stroke engine with 95% of rice bran oil and 5% of ethanol, 90% of rice bran oil and 10% of ethanol, 85% of rice bran oil and 15% of ethanol and its brake thermal efficiency

Table 2. Data for different biodiesel production costs (Wakil et al. 2014).

Name of the vegetable oil	Cost for per litre oil (Tk.)	Cost of methanol (Tk.)	Cost of catalyst (Tk.)	Cost of biodiesel without methanol recovery (Glycerin and soap) (Tk.)	Amount of biodiesel (L)	Total Cost of biodiesel per litre (Tk.)
Jatropha (Wakil et al. 2016)	80.5	2305	-	2385.5	0.9	2650.5
Neem (Wakil et al. 2016)	82.5	2160	11.0	2253.5	0.95	2372.1
Castor (Wakil et al. 2016)	74	2160	30.0	2264	0.9	2515.55
Sunflower (Wakil et al. 2016)	167.56	133.33	4.67	305.56	0.7	436.51
Coconut (Wakil et al. 2016)	168	160	5.6	333.6	0.75	444.8
Rice Bran	155	189	12.0	358.5	0.74	489.39

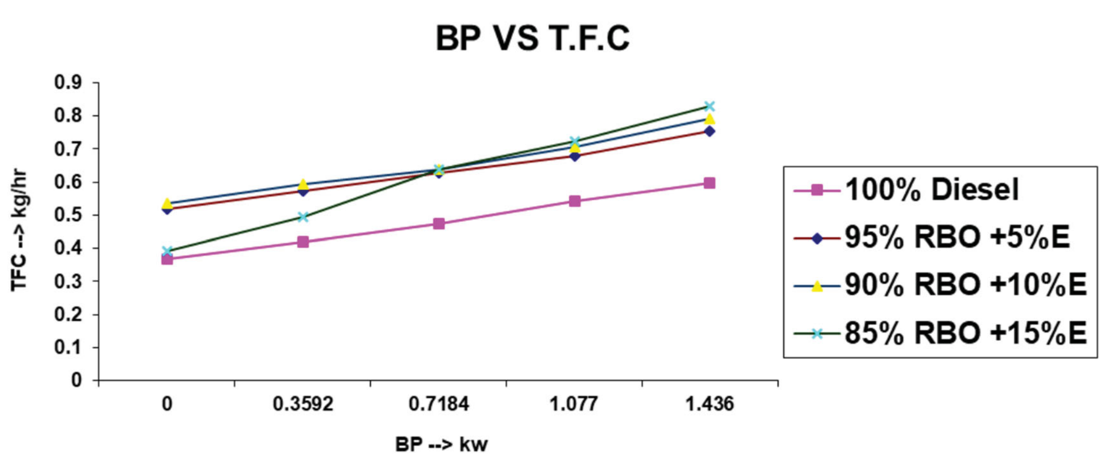

Figure 2. Break power vs total fuel consumption.

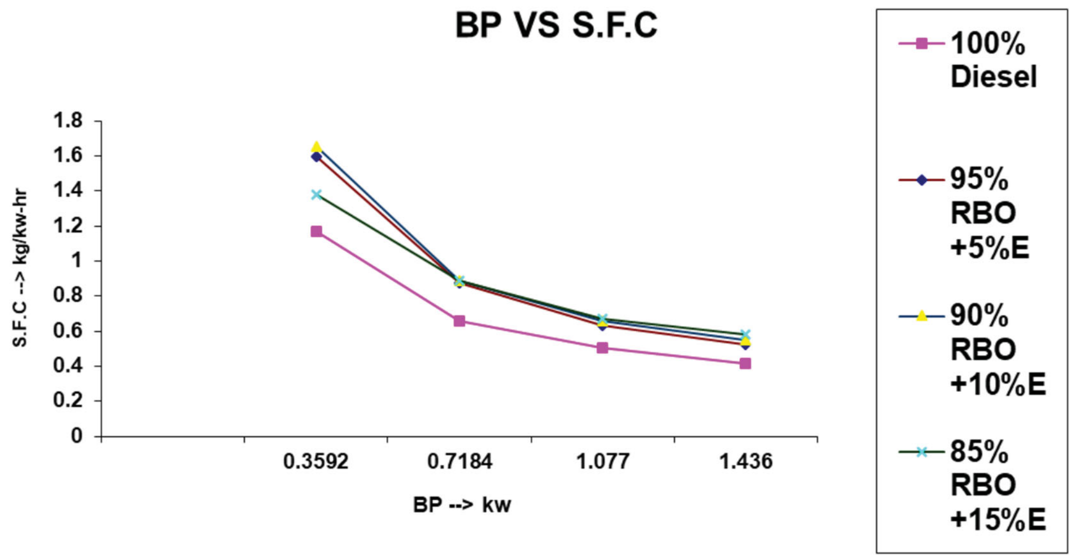

Figure 3. Break power vs specific fuel consumption.

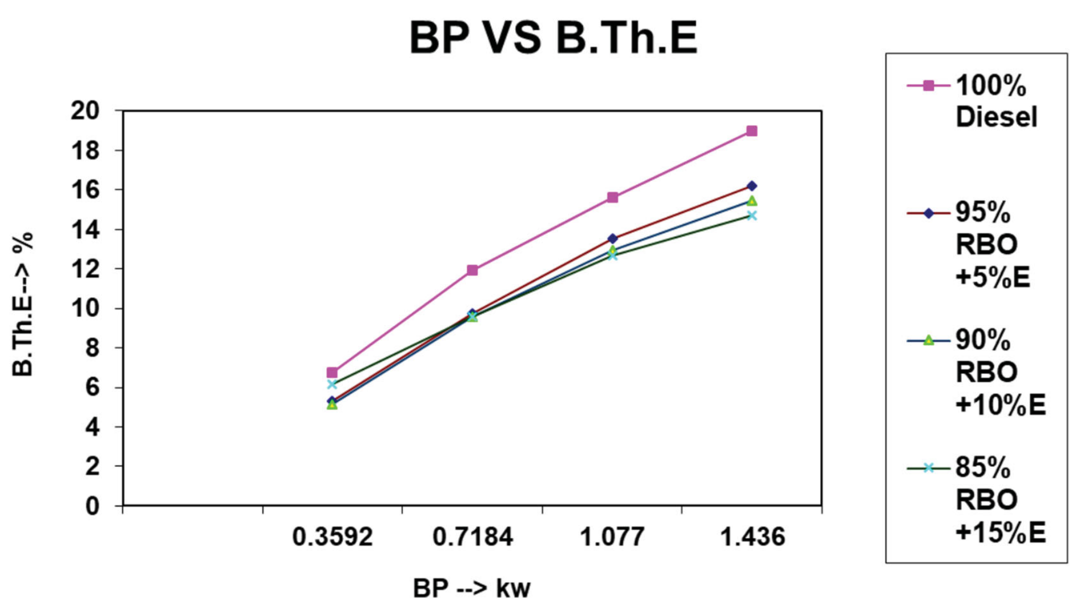

Figure 4. Break power vs break thermal efficiency.

obtained during combustion is plotted against 100% diesel (Figures 2–4).

Ninety-five per cent of rice bran oil and 5% of ethanol show better characteristics than the other two propositions. No engine modification is needed and no change in valve timings of diesel fuel is required.

13. Reduction of emission of fuel

Biofuel have the problem of high oxidising capacity, so emission of NO*x* is slightly higher. Reduction in emission of toxic gases like CO (carbon monoxide), NO*x* (nitrous oxide), HC (hydrocarbons) is done by a three-way catalytic converter. A closed loop air-fuel ratio controller is required for the three-way catalyst to work effectively (Figure 5).

To prevent CO and HC emission, oxidation is required, the reaction that takes place in the catalytic converter is

$$CO + 1/2\,O_2 \rightarrow CO_2 \; HC + 1/2\,O_2 \rightarrow CO_2 + H_2O$$

To prevent NO emission, both oxidation and reduction are required, the reaction that takes place in the catalytic converter is

$$CO + NO \rightarrow 1/2\,N_2 + CO_2$$

14. Additives used in bio fuel

During extremely colder conditions thickening of bio fuel will take place. In order to avoid the problem basically we depend on external agents and electrical heaters. Ethanol externally added

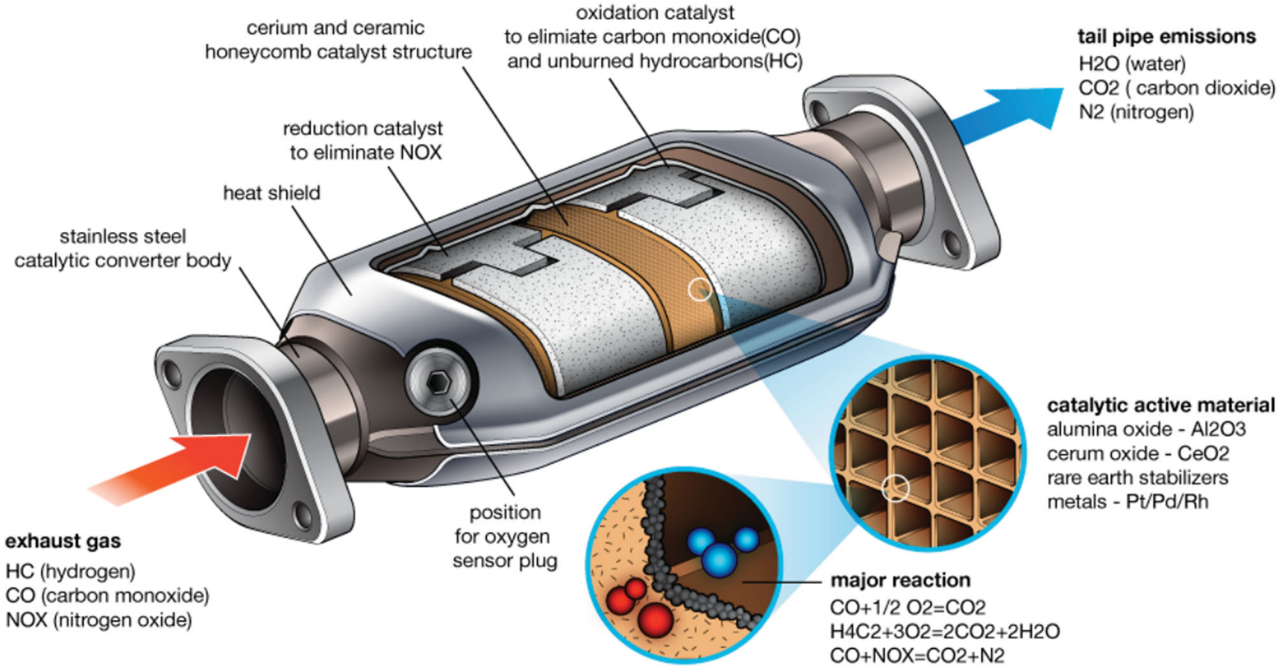

Figure 5. Reduction of emission.

will provide clean burning and also acts as an anti-gel forming agent. Kerosene may also acts as an additive to avoid gel formation. Other anti-gel forming agents are toxic and contain toluene.

15. Method for preventing degrading of hoses and valves

Since biodiesel is an alcohol it eventually degrade seals and hoses that are not rated for alcohol. The most common material for making alcohol-resistant seals and hoses is 'Fluoro-elastomer', the most common of this is called viton which is made of Dupont. Also the most common diesel engine uses viton seals and hoses with viton lining.

16. Conclusion

From the test conducted on the constant speed diesel engine, based upon the results discussed, without any engine modifications, the blend of ethanol with rice bran oil is recommended for the following reasons:

- Brake thermal efficiency is nearly equal to diesel.
- Specific fuel consumption and total fuel consumption are better.
- Low emission.
- No engine modifications required.
- Improved cold weather performance.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

I. Vinoth Kanna http://orcid.org/0000-0001-8194-8781

References

Anon. 2017. "Non Conventional Energy Source for Small Capacity Diesel Engine From High ffa Rice Bran oil." *International Journal of Advance Engineering and Research Development* 4 (03), Available at: http://dx.doi.org/10.21090/ijaerd.isnch01.

Bakota, E. L., et al. 2013. "Solvent Fractionation of Rice Bran oil to Produce a Spreadable Rice Bran Product." *European Journal of Lipid Science and Technology* 115 (8): 847–857. Available at: http://dx.doi.org/10.1002/ejlt.201200355.

Bio diesel Technologies in India (The soil to oil people) – Home - http://www.biodieseltechnologiesindia.com/ricebranoil.html

Devaraj, A., I. Vinoth kanna, K. Manikandan, and Jishuchandran. 2017. "Impact of Engine Emissions from HCCI Engine, An Overview." *International Journal of Mechanical and Production Engineering Research and Development* 7 (6): 501–506. doi.org/10.24247/ijmperddec201757.

Devaraj, A., D. Yuvarajan, and I. Vinoth Kanna. 2018. "Study on the Outcome of a Cetane Improver on the Emission Characteristics of a Diesel Engine." *International Journal of Ambient Energy*, 1–4. https://doi.org/10.1080/01430750.2018.1492452.

Fadhil, A. B., A. M. Aziz, and M. H. Altamer. 2016. "Potassium Acetate Supported on Activated Carbon for Transesterification of New Non-Edible oil, Bitter Almond Oil." *Fuel* 170: 130–140. doi.org/10.1016/j.fuel.2015.12.027.

Guo, F., and S. Aryana. 2016. "An Experimental Investigation of Nanoparticle-Stabilized CO_2 Foam Used in Enhanced oil Recovery." *Fuel* 186: 430–442. doi.org/10.1016/j.fuel.2016.08.058.

Hua, Z., et al. 2016. "Effect of Injection Brine Composition on Wettability and oil Recovery in Sandstone Reservoirs." *Fuel* 182: 687–695. doi.org/10.1016/j.fuel.2016.06.009.

Inoue, H., and T. Noguchi. 1964. "Direct Extraction of Rice Bran Oil with Lower Acid Value From Rice Bran." *Journal of Japan Oil Chemists' Society* 13 (4): 206–210. doi.org/10.5650/jos1956.13.206.

Jongjareonrak, A., et al. 2015. "Extraction and Fundamental Properties of Protein from De-Oiled Rice Bran of Rice Bran Oil Production Industry." *Chiang Mai University Journal of Natural Sciences* 14 (2). doi.org/10.12982/cmujns.2015.0079.

Kumar, S. S., M. W. Iruthayarajan, and M. Bakrutheen. 2016. "Investigations on the Suitability of Rice Bran oil and Corn oil as Alternative Insulating Liquids for Transformers." *IEEJ Transactions on Electrical and Electronic Engineering* 11 (1): 10–14. doi.org/10.1002/tee.22182.

Kumar Sharma, H., et al. 2006. "Thermal Behavior of Pure Rice Bran oil, Sunflower oil and Their Model Blends During Deep fat Frying." *Grasas y Aceites* 57 (4). doi.org/10.3989/gya.2006.v57.i4.62.

Lakkakula, N. R., M. Lima, and T. Walker. 2004. "Rice Bran Stabilization and Rice Bran oil Extraction Using Ohmic Heating." *Bioresource Technology* 92 (2): 157–161. doi.org/10.1016/j.biortech.2003.08.010.

Mishra, R., H. K. Sharma, and G. Sengar. 2012. "Quantification of Rice Bran oil in oil Blends." *Grasas y Aceites* 63 (1): 53–60. doi.org/10.3989/gya.033311.

Nagappan, M., and I. Vinoth Kanna. 2018. "A Novel Technique and Detailed Analysis of Cars in Indian Roads to Adopt low Ground Clearance." *International Journal of Ambient Energy*, 1–7. doi.org/10.1080/01430750.2018.1501753.

Nakajima, S., et al. 2017. "Autoxidation of Fish Oil Blended with Rice Bran Oil." *Journal of Oleo Science* 66 (6): 573–577. doi.org/10.5650/jos.ess17030.

Narayan, A. V., R. S. Barhate, and K. S. M. S. Raghavarao. 2006. "Extraction and Purification of Oryzanol From Rice Bran oil and Rice Bran Oil Soapstock." *Journal of the American Oil Chemists' Society* 83 (8): 663–670. doi.org/10.1007/s11746-006-5021-2.

Pal, Y. P., and A. P. Pratap. 2017. "Rice Bran Oil: A Versatile Source for Edible and Industrial Applications." *Journal of Oleo Science* 66 (6): 551–556. doi.org/10.5650/jos.ess17061.

Park, H.-S., K.-M. Choi, and G.-D. Han. 2008. "Changes of Breadmaking Characteristics with the Addition of Rice Bran, Fermented Rice Bran and Rice Bran Oil." *Journal of the Korean Society of Food Science and Nutrition* 37 (5): 640–646. doi.org/10.3746/jkfn.2008.37.5.640.

Parthiban, K. S., and M. Perumalsamy. 2016. "Kinetic Studies on oil Extraction and Biodiesel Production from Underutilized *Annona squamosa* Seeds." *Fuel* 180: 211–217. doi.org/10.1016/j.fuel.2016.04.020.

Paturu, P., and I. Vinoth kanna. 2018. "Experimental Investigation of Performance and Emissions Characteristics on Single-Cylinder Direct-Injection Diesel Engine with PSZ Coating Using Radish Biodiesel." *International Journal of Ambient Energy*, 1–10. doi.org/10.1080/01430750.2018.1492455.

Ponchurdchai, C., and J. Singkhonrat. 2016. "Monitoring the Effect of Different Storage Conditions of Cold-Pressed Rice Bran Oil." *International Journal of Chemical Engineering and Applications* 7 (4): 254–258. doi.org/10.18178/ijcea.2016.7.4.584.

Prichapan, N., D. J. McClements, and U. Klinkesorn. 2017. "Influence of Rice Bran Stearin on Stability, Properties and Encapsulation Efficiency of Polyglycerol Polyricinoleate [PGPR]-Stabilized Water-in-Rice Bran oil Emulsions." *Food Research International* 93: 26–32. doi.org/10.1016/j.foodres.2017.01.007.

Rani, S. 2017. "The Evaluation of Lubricant Properties and Environmental Effect of bio-Lubricant Developed From Rice Bran oil." *International Journal of Surface Science and Engineering* 11 (5): 403. doi.org/10.1504/ijsurfse.2017.10009252.

Reyhanitash, E., et al. 2016. "Hydrotreatment of Fast Pyrolysis oil: Effects of Esterification pre-Treatment of the Oil Using Alcohol at a Small Loading." *Fuel* 179: 45–51. doi.org/10.1016/j.fuel.2016.03.074.

Saravanan, S., G. Nagarajan, and G. Lakshmi Narayana Rao. 2008. "Effect of FFA of Crude Rice Bran Oil on the Properties of Diesel Blends." *Journal of the American Oil Chemists' Society* 85 (7): 663–666. doi.org/10.1007/s11746-008-1246-6.

Sayasoonthorn, S., S. Kaewrueng, and P. Patharasathapornkul. 2012. "Rice Bran Oil Extraction by Screw Press Method: Optimum Operating Settings, Oil Extraction Level and Press Cake Appearance." *Rice Science* 19 (1): 75–78. doi.org/10.1016/s1672-6308[12]60024-9.

Saydut, A., et al. 2016. "Process Optimization for Production of Biodiesel from Hazelnut oil, Sunflower oil and Their Hybrid Feedstock." *Fuel* 183: 512–517. doi.org/10.1016/j.fuel.2016.06.114.

Utarwuthipong, T., et al. 2009. "Small Dense Low-Density Lipoprotein Concentration and Oxidative Susceptibility Changes after Consumption of Soybean Oil, Rice Bran Oil, Palm Oil and Mixed Rice Bran/Palm Oil in Hypercholesterolaemic Women." *Journal of International Medical Research* 37 (1): 96–104. doi.org/10.1177/147323000903700111.

Vinoth kanna, I. 2018. "Modelling and Analysis of the Thermal Behavior of air Cooling System with fin Pitch in IC Engines." *International Journal of Ambient Energy*, 1–16. doi.org/10.1080/01430750.2018.1507939.

Vinoth kanna, I. 2018b. "Optimization of the Evaporator of a Refrigerator Employing Hydrocarbon as a Refrigerant." *International Journal of Ambient Energy*, 1–9. doi.org/10.1080/01430750.2018.1507943.

Vinoth Kanna, I., A. Devaraj, and K. Subramani. 2018a. "Bio Diesel Production by Using Jatropha: the Fuel for Future." *International Journal of Ambient Energy*, 1–7. doi.org/10.1080/01430750.2018.1456962.

Vinoth Kanna, I., and P. Paturu. 2018. "A Study of Hydrogen as an Alternative Fuel." *International Journal of Ambient Energy*, 1–4. doi.org/10.1080/01430750.2018.1484803.

Vinoth kanna, I., and D. Pinky. 2018a. "Automatic Seat Level Control Using MEMS Programmed with Lab VIEW." *International Journal of Ambient Energy*, 1–4. doi.org/10.1080/01430750.2018.1484813.

Vinoth Kanna, I., and D. Pinky. 2018b. "Solar Research – A Review and Recommendations for the Most Important Supplier of Energy for the Earth with Solar Systems." *International Journal of Ambient Energy*, 1–7. doi.org/10.1080/01430750.2018.1472658.

Vinoth kanna, I., and D. Pinky. 2018c. "Investigation of the Effects of Exhaust and Power Loss in Dual Fuel six Stroke Engine with EGR Technology." *International Journal of Ambient Energy*, 1–9. doi.org/10.1080/01430750.2018.1507942.

Vinoth Kanna, I., A. Vasudevan, and K. Subramani. 2018b. "Internal Combustion Engine Efficiency Enhancer by Using Hydrogen." *International Journal of Ambient Energy*, 1–4. doi.org/10.1080/01430750.2018.1456961.

Wakil, M. A., et al. 2016. "Rice Bran: A Prospective Resource for Biodiesel Production in Bangladesh." *International Journal of Green Energy* 13 (5): 497–504. doi.org/10.1080/15435075.2014.966374.