International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 8 ǁ August. 2013 ǁ PP.75-79

Alternative Diesel Engine Fuel from Kenyan Pishori Rice Bran.

Wahome A[*1]., Ngunjiri G.M.N[2]., Shitanda D[3]., Ogola W.O[4]

[1.] *University of Nairobi- Department of Electrical and Information Engineering*
[2.] *Egerton University – Department of Agriculture Engineering*
[3.] *Multimedia University College- Research production and Extension Division*
[4.] *Technical University of Kenya- Department of Mechatronics Engineering*

ABSTRACT: Rice *bran used as biomass material was acquired from small scale rice millers in Wang'uru-Mwea, Kirinyaga County, Kenya. The oil was extracted from the rice bran using petroleum ether which was preferred due to its high affinity for oil and ease of recovery due to its low boiling point of* 40^o *-*60^o*. The percentage of free fatty acids in the rice bran oil was determined by titration method and was found to be 3.22%. Acid catalyzed pretreatment was used to lower the free fatty acids to less than 2.5% to allow transesterification of the rice bran oil to biodiesel. The following biodiesel characteristics were determined using ASTM methods; Density at* 20^oC*, Viscosity at* 40^oC*, Flash point, Cetane index, Copper strip corrosion, Ash content, pH value, refractive index, distillation point and Calorific value. The density of the biodiesel was higher than the acceptable ASTM 1298 range by 1.4% and the calorific value of diesel was 45.52MJ/Kg while that of biodiesel was 38.92MJ/Kg amounting to 14.5% decrease. Viscosity, flash point, boiling range, cetane index, and copper strip corrosion were all within the specified ASTM range for diesel fuel. The ash content was 0.5% compared the specified maximum of 0.01% for diesel this was attributed to the oil extraction method and the level of FF. The pH value was low and though this could not affect the performance of the biodiesel as a fuel it can cause the corrosion of the metallic parts of the fuel systems as well as the engine walls. The refractive index of the biodiesel was approximately the same as that of diesel.*

I. INTRODUCTION

Energy from renewable sources accounts for the bulk of the primary materials upon which future development strategies are directed. Bio-diesel has attracted a great deal of interest during the past decade as a renewable, biodegradable, reduced toxicity and eco-friendly clean fuel which can be used in a diesel engine without engine modification (Kinast, 2003). Since diesel engine is optimized for diesel fuel, a fuel with properties closer to those of diesel is desired to avoid engine modifications. Therefore, modifying vegetable oils through chemical reaction with alcohol (transesterification) to produce the methyl or ethyl esters (biodiesel) is essential for successful long term engine operation (Encinar, 2005).

Rice bran oil, though classified as minor oil, is a potential source of biodiesel due to the availability of millions of tonnes of rice bran from the rice milling process worldwide. In 2007/2008, Kenya's total rice production was 53,115 tonnes out of which 51,458 tonnes was from Pishori rice grown in Mwea Irrigation Scheme (CBS, 2008). Plans are underway to rehabilitate and expand the area under rice cultivation in Kenya, from the current 12,083 hectares to 29,840 hectares by the year 2030. This aims to more than doubling the annual rice production (NIB, 2007).

Most rice varieties are composed of roughly 20% hull, 11% bran, and 69% starchy endosperm (Gupta *et al*, 2007). Thus 1Kg of harvested rice produces approximately 0.11Kg (110g) of rice bran. Rice bran is the thin shell that immediately surrounds the rice kernel. It is removed during the milling/polishing process as the oil in it quickly becomes rancid thus reducing the shelf life of rice (Mondal, 2008). It contains approximately 10 - 25% extractable oil depending on the degree of milling, rice variety, and other agro-climatic factors (Umer *et al*., 2009). Thus considering average of 20% extractable oil, 1Kg of harvested rice can produce approximately 22g of oil.

II. MATERIALS AND EXPERIMENTAL SETUP

2.1 Experimental Setup

Rice bran was acquired immediately after milling from small scale rice millers in Mwea, Kenya and taken to Jomo Kenyatta University of Agriculture and Technology, for stabilization of the bran using the oven method and extraction of rice bran oil using petroleum ether in a solvent extractor. The extracted oil was processed to rice bran oil methyl ester through esterification and transesterification process. The experimental analysis was carried out using standard methods recommended by ASTM and AOAC. However, for the properties which could not be determined using the recommended methods due to unavailability of facilities, alternative improvised methods were used. The density was determined at 20^oC, viscosity at 40^oC together with flash point, copper corrosion and distillation were all determined at chemical laboratory, Kenya Pipeline Company. The refractive index, ash content, sulfur and pH were determined at the Department of Food Science and Technology, Jomo Kenyatta University of Agriculture and Technology. Calorific value was determined at the physical chemistry laboratory, Kenyatta University.

2.2 Determination of Density

This was done automatically at 20^oC using
ASTM 1298. ADM- Mettler Toledo DE40 equipment was used and the specific gravity calculated as follows.

$$\text{Specific Gravity} = \frac{\rho}{\rho_{ref}} \qquad (1.1)$$

Where ρ_{ref} is the density of water at 4^oC (1g/cm^3)

2.3 Determination of Flash Point

The flash point was determined using ASTM 93. A manual Pensky Martens closed cup apparatus was used to determine the flash point. A brass test cup was filled with the sample up to the inside mark, fitted with a cover and placed in a properly locked apparatus. A flame of 3.2 - 4.8mm diameter was used to heat the sample at a temperature rate of between 5- 6^oC at a stirring speed of 90rpmWhen the temperature reached the flash point, the vapour ignited and an easily detectable flash was observed.

$$\text{Corrected flash point} = C + 0.33(760 - P) \qquad (1.2)$$

Where
C = the recorded flash point
P = the ambient barometric pressure, mmHg

2.4 Determination of Viscosity

The viscosity of the oil was determined using ASTM 445. Pm Tamson Thermostatic bath was filled with water up to float level, the temperature set to 40^oC for at least one hour, to ensure stability of the bath temperature. Cannon Fenske opaque viscometer S100 with lower bulb and upper bulb constant of 0.01627 and 0.01200 respectively was used. The viscometer was calibrated using distilled water at 1.004mm^2/s at 20^oC.

2.5 Distillation of Biodiesel

The boiling range characteristics of the biodiesel were determined for the calculation of cetane index using ASTM 86. 100ml of biodiesel was distilled in a laboratory batch distillation unit, Seta Still Distillation Tester at 22^oC. Systematic observations of temperature readings and volume of the condensate were made every two seconds using thermometer 8C with a temperature range of negative 2^oC to 400^oC.

2.6 Determination of Cetane Index

The cetane index was calculated to approximate the cetane number using ASTM 976 empirical formula even though it only provides accurate indication of the cetane number for pure petroleum fuels.

2.7 Determination of Calorific Value

The calorific value was determined using the Gallen Kamp Auto Bomb. The sample weight, initial and final temperatures were recorded and used to compute the caloric value using the following equation.

$$\text{Calorific Value} = \frac{(\Delta T - C_T) - K}{W_S} \qquad (1.3)$$

Where
ΔT = Final temperature – Initial temperature
C_T = Total heat capacity of apparatus used (10.380J/^oC)
K = Constant Heat gain (0.126^oC)
W_s = Sample Weight

2.8 Determination of Ash Content

This was done using dry ashing method muffle furnace heated at 550oC in Advantech KL-4202 muffle furnace. The ash content was calculated as follows

$$\%Ash = \frac{W_2 - W_0}{W_1 - W_0} \times 100 \qquad (1.4)$$

Where
W_0 = Weight of empty crucible in grammes
W_1 = Weight of crucible with sample in grammes
W_2 = Weight after ashing in grammes

2.9 Determination of Ph

The pH meter was calibrated using 4.01and 6.86pH buffers sequentially. The electrode was washed using distilled water and dried, dipped in to the sample in a beaker and the pH value read from the digital screen of the pH meter.

2.10 Determination of Refractive Index

Abbe refractometer was used to determine the refractive index. Two drops of oil were placed in the lower prism of the refractometer and the mirrors were adjusted to give the sharpest reading. The refractive index was read from the upper scale of the refractometer up to four decimal places.

2.11 Determination of Copper Strip Corrosion 30ml of sample was added to polished copper strips in test tubes and placed in Stan Hope Seta Copper Corrosion Bath for 3hours at 100^{o}C. The strips were removed and compared with the copper strip classification table provided by Gerpen *et al.,* 2004.

III. RESULTS AND DISCUSSION

Characterization of diesel and biodiesel was done and the results are as tabulated in table 3.1. ASTM standards were used to verify if the quality of the biodiesel was within the acceptable limits.

Table 3.1 Fuel characterization data for Diesel and Biodiesel

	Sample Identity			
Property	Diesel	Biodiesel	ASTM Standards	ASTM Method
Density @ 20^{o}C (g/m^{3})	0.831	0.883	0.820-0.870	ASTM1298
Viscosity @ 40^{O}C mm^{2}/s	3.2	5.45	1.6-5.5	ASTM 445
Flash point (^{o}C)	62.5	155.7	130 (min ME)	ASTM 6751
Cetane index	47.37	52.56	48	ASTM 976
Ash Content	0.005	0.5	Max 0.01	ASTM482
Acid Value(mgKOH/g)	0.125	0.912	0.8	ASTM664
Sulfur	0.001	-	Max 0.05	ASTM 1582
Copper corrosion	1A	1B	1	ASTM 130
Distillation at 90%(^{o}C)	330	351	400	ASTM 86
Calorific Value (KJ/Kg)	45.52	38.92	-	-
Refractive Index	1.34	1.4608	-	-

3.1 Density

The specific gravity of the biodiesel was 0.882g/cm^3, which was not within the ASTM standard. High specific gravity would lead to poor fuel atomization.

3.2 Viscosity

The viscosity of the biodiesel was higher than that of diesel but well within the recommended ASTM range. High viscosity causes poor atomization of the fuel leading to poor combustion.

3.3 Flash Point

According to ASTM Biodiesel Standard D 6751, the minimum flash point for biodiesel should be at 130°C. The flash point of rice bran biodiesel was 155.7 which was above the set minimum value. This could have been as a result of double bonds in the biodiesel. The flash point complied with the ASTM standard and also with the results obtained by (Madyira *et al.*, 2012), who studied the characterization of sunflower biodiesel and found the flash point to be 182.82^{o}C. Though the flash point of the biodiesel fuel has no relation to its performance in the engine, or to its auto ignition qualities, high flash point leads to increased fuel safety thus easier to transport, reduced fire risks, easy to store and handle. Disadvantages of high flash point include increased engine operation heat, higher loses, larger pressures, temperatures and reduced overall cycle efficiency

3.4 Cetane Index

The cetane number of the biodiesel was above the minimum ASTM value of 130 even though it was approximated using the cetane index. Fuels with higher cetane index have short ignition delay and thus small amount of premixed combustion.

3.6 Ash Content

The ash content of the biodiesel was higher compared to diesel. This could be attributed to the chemical extraction of rice bran oil as the reaction between the oils and the extraction solvent must have resulted in non combustible products. High ash content leads to soot formation in the engine. Mechanical extraction of the oil could ease the problem of engine deposits but the quantity of oil extracted mechanically was too small and uneconomical in terms of acquiring the bran and running costs of the screw expeller. Refining should be done to remove the FFA and gums which contribute to high ash content but this will increase the cost of the biodiesel.

3.7 pH Value

The pH value was low and this was attributed to the use of acid catalyst during esterification process to reduce the level of FFA. Though the pH value does not affect the performance of the biodiesel as a fuel, low pH value poses a threat to some of the engine's operating components, primarily the fuel injection system through corrosion of the metallic parts of the fuel system and the engine walls leading to tear and wear. The free fatty acids increase the acidity levels in biodiesel. Incomplete conversion from fatty acids to methyl esters left traces of the fatty acids and resulted in low pH values. The acid number of biodiesel is also dependent on the fatty acids contained in the vegetable oil. The acidity could also have been influenced by the production process and traces of sulfuric acid and soap formation from the methanol and the sodium hydroxide used.

3.8 Sulfur Content

Sulfur was not detected in the biodiesel as the level was below the detectable level using the AOAC. However, diesel had sulfur content of 0.046. This indicated that when biodiesel is used as a diesel fuel additive it will result in a decrease of sulfur content. The maximum Sulfur content permitted by ASTM1582 is 0.5%.

3.9 Copper Strip Corrosion

Results obtained for copper strip corrosion of biodiesel was 1B, but that of diesel 1A meaning the strips were slightly tarnished as defined on the copper trip classifications. 1A means that the strip was slightly tarnished and looked almost the same as a freshly polished strip after the test while 1B was slightly tarnished, but looked darker than 1A. The results conform to the ASTM 975.

3.10 Calorific value

The calorific value of diesel was found to be 45.52 MJ/kg while that of biodiesel was found to be 38.92 MJ/kg, which is a difference of 14.5%. This was higher than 7.07% difference found by Krishnakumar (2008), who studied the fuel properties of various biodiesels and found the calorific value of rice bran biodiesel to be 41.2MJ/Kg and that of diesel 44.34Mj/Kg. As the density of biodiesel was higher than that of diesel fuel, 882.5g/l and 830.7g/l respectively at 20°C, the calorific value was affected thus affecting the air fuel ratio. Since fuel injection is measured by volume as opposed to mass, the biodiesel had a higher mass in the same volume. Therefore the density of the fuel had a direct influence on the power output. The energy content on volume basis was 37.81MJ/L for diesel and 34.35MJ/L for biodiesel. The low calorific value for the biodiesel would result to increased fuel consumption.

3.11 Refractive Index

The refractive index for the diesel and biodiesel was approximately the same indicating similar characteristics in both fuels.

IV. CONCLUSION

The rice bran oil biodiesel characterization measurements were made according to relevant ASTM standards. This insured the structural integrity and safety of the engine. The determined values of viscosity, cetane index, flash point, distillation, and copper corrosion were within the stipulated range as per ASTM standards. The high density, low viscosity and low calorific value were comparable to the results obtained by Kinast (2003) who studied the characteristics of seven methyl esters and also Krishnakumar, 2008 who studied the fuel properties of vegetable oil esters. The high density, low viscosity and low calorific value would raise the BSFC of the diesel engine using rice bran oil biodiesel as determined by Xue *et al.*, 2010. Rice bran oil biodiesel can be effectively used as fuel in a diesel engine as its properties are within the recommended standard fuel range as shown in table 3.1

V. REFERENCES

[1] Central Bureau of Statistics, (2008). Ministry of Planning and National Development, Economic Survey.
[2] Encinar, A., (2005). Bio-diesel from Used Frying Oil. Bioresource Technology, Vol. 44 pp 91-99.
[3] Gerpen J.V., Shanks B., Pruszko R., (2004). Bio-diesel Analytical Methods. Report Prepared for National Renewable Energy Laboratory - U.S. Department of Energy, Colorado.
[4] Gupta, P.K., Kumar, R., Panesar, B.S., Thapar, V.K., (2007). Parametric Studies on Bio-diesel
[5] prepared from Rice Bran Oil. Agriculture Engineering International, Vol. 9 pp 6-18.
[6] Kinast J., (2003). Production of Bio-diesel from Multiple Feedstock and Bio-diesel Technology. Report Prepared for National Renewable Energy Laboratory – U.S. Department of Energy Colorado.
[7] Krishnakuma J., Venkachalapathy K.V.S., Elancheliyan S., (2008). Technical Aspect of Biodiesel Production from vegetable Oils. Thermal Science Vol. 12 pp 159-169
[8] Madyira D.M., Nkomo Z., Akinlabi T.E., (2012). Proceedings of World Congress on Engineering. Vol. III WCE 2012, London U.K.
[9] Mondal, P., Basu, M., Balasubramanian, N., (2008). Direct Use of Vegetable Oil and Animal fat as Alternative Fuel in Internal Combustion Engine. Biofuels, Vol. 2 pp 155-174.
[10] National Irrigation Board, (2007). Progress and Production of Irrigation Schemes accessed online
[11] at http://www.nib.or.ke/index.php
[12] Umer, R., Anwar, F., Ansari, T.M., Arif, M., Ahmad, M., (2009). Optimization of Alkaline Transesterification of Rice Bran Oil for Bio-diesel Production Using Response Surface Methodology, Vol. 84, pp 64-70.