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Investigation of Fuel Properties of Crude Rice Bran Oil Methyl Ester and Their Blends with Diesel and Kerosene

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ABSTRACT : *In this paper characteristic fuel properties of crude rice bran oil methyl ester((RBOME) and its blends with conventional diesel oil in the proportions of 20:80(B20), 40:60(B40), 60:40(B60), 80:20(B80) and 100:0(B100) respectively were studied. Rice bran oil methyl ester was prepared from crude rice bran oil by using three stage transesterification processes. In the first two stages,* H_2SO_4 *was used as an acid catalyst to reduce the free fatty acid (FFA) level to less than 1%. In the third stage, NaOH was used as an alkaline catalyst to complete the transesterification reaction with methanol. Fuel properties such as viscosity, gross calorific value, flash and fire points were compared with conventional diesel oil to study their usefulness as compression ignition fuel. The characteristics fuel properties of RBOME blends were found to deviate more from those of diesel oil with the increasing in the percentage of methyl ester in the blend. It was also found that the properties of blend of B20 were found very close to those of conventional diesel oil. In addition, an attempt has made to reduce diesel proportion in blends by adding domestic kerosene in the proportions (methyl ester: conventional diesel: kerosene) of 20:75:5, 40:50:10, 60:25:15 and 80:0:20 respectively were studied.*

KEYWORDS: *crude rice bran oil methyl ester, conventional diesel oil, Rice bran oil, transesterification*

I. INTRODUCTION

Unpredictable prices of crude oil have pessimistic impact on the foreign exchange reserves of oil importing countries like India. Limited non-renewable energy sources, depleting reserves of fossil fuels, increasing demand for diesel oil, and uncertainty in their availability and increasing stringent environmental regulations has motivated an intense search for an alternative transportation fuel over the last three decades **[1]**. Biodiesel (Methyl or ethyl ester) is one of the options as an alternative transport fuel which has received attention all over the world as an alternative automotive fuel because they are renewable and eco-friendly **[2]**. Generally, biodiesel is defined as oxygenated, sulphur free, bio-degradable, non toxic and eco–friendly alternative diesel oil **[3] [4].** It can also chemically be defined as fuel composed of mono-alkyl esters of long chain fatty acids derived from renewable sources such as straight vegetable oil (edible and non edible), animal fats and oils and waste cooking oil and fried oil . It is designated as B100 **[5] [6].Lot of** research work has been done on investigation of the properties of methyl esters of vegetable oils. It was reported that properties of methyl ester are very close to diesel oil **[7] [8].** It was also reported that properties of methyl ester deviates more from diesel oil with the increase in the percentage of ester in the blend because ester has nearly 10% lower calorific value than diesel oil **[9]**. This results in minor change in engine performance and engine emissions. However, methyl ester has higher cetane number, no aromatics and contains 10% to 11% O_2 by weight which reduces the emission of carbon monoxide (CO) and Un-burnt Hydrocarbon (UNBHC) and particulate matter (PM) in the exhaust gas **[10]**.

Many researchers have studied the properties of vegetable oils in order to substitute for diesel oil. The fuel properties of vegetable oils **[11] [12][13]** as listed in the Table I: indicate that, the kinematic viscosity of vegetable oils varies from 18.2 cSt to 66.2 cSt at 38^0C. The high viscosity of these oils is due to their high molecular weight in the range of 600 to 900, which is about 20 times that of diesel oil. The flash point of vegetable oils is extremely high (above the 150^0C). The heating values of the vegetable oils (39 to 40 MJ/kg) are lower than diesel oil (about 45 MJ/kg). The presence of chemically bound oxygen in vegetable oils reduces their heating values by approximately 10%.

Table I: Properties of vegetable oils

Vegetable oil	Kinematic Viscosity at 38 ^{0}C (mm^2 / s)	Heating Value (MJ/kg)	Flash point (^{0}C)	Density (kg/l)
Soybean	32.6	39.6	254	0.9138
Sunflower	33.9	39.6	274	0.9161
Peanut	39.6	39.8	271	0.9026
Palm	39.6	-	267	0.9180
Rapeseed	37.0	39.7	246	0.9115
Jatropha oil	18.2	38.5	174	0.920
Rubber seed	66.2	37.5	198	0.910
Pongamia	27.84	34.0	205	0.913

Many researchers reported that the viscosity of waste cooking oil, canola oil, corn oil and jatropha oil has reduced to 5.3 mm^2/sec, 2.56 to2.84 mm^2/sec, 2.45 to 2.56 mm^2/sec and 2.35 to 2.47 mm^2/sec at 40^{0}C respectively after transesterification process **[14] [15]**. Some researcher reported that viscosity is an important transport property of fuel and also reported that it strongly affect the flow behavior at different temperatures **[16] [17].** In general, viscosity increases with the increase in un-saturation. So, vegetable oil containing low molecular weight tricylglycerol is slightly less viscous than the oil containing high molecular weight tricylglycerol. Researchers have also studied the properties of blends of methyl ester and conventional diesel oil as a substitute for diesel oil. These oils include rapeseed oil, tallow, soybean, cotton seed and other seed oils **[18]**. In this paper, an attempt has made to investigate the fuel properties of crude rice bran oil methyl ester and its blends with conventional diesel oil to study their usefulness as a compression ignition engine fuel.

II. MATERIAL AND METHOD

Rice bran oil methyl ester was prepared by using three-stage transesterification process because their free fatty acids (FFA) level is greater than 1%. In the first stage, esterification reaction was carried out by adding 15ml methanol to 100ml of rice bran oil, and 0.5ml H_2SO_4. This reaction was carried at temperature range between 55^{0}C to 60^{0}C with a reaction period of 60 minutes using magnetic stirrer. In the second stage, 7ml methanol was added to the sample(100ml) obtained from the first stage with 0.5ml H_2SO_4 with reaction time of 75minutes and temperature range of 55^{0}C to 60^{0}C. Then in third stage, transesterification reaction was completed by adding 15ml of methanol to the sample (100ml) obtained from previous stage and 0.5grams of NaOH with reaction time of 60minutes and temperature range of 55^{0}C to 60^{0}C using magnetic stirrer. Rice bran oil methyl ester-diesel oil blends were prepared by mixing 20% (B20), 40% (B40), 60% (B60) and 80% (B80) respective methyl ester with diesel oil on volume basis. In addition another four blends were prepared by replacing diesel oil proportion by 5% (B20K5), 10% (B40K10), 15% (B60K15) and 20% (B80K20) respectively in B20, B40, B60 and B80 with domestic kerosene oil on volume basis. The fuel properties such as density, kinematic viscosity, gross calorific value, flash point, fire point of diesel oil, crude rice bran oil, crude rice bran oil methyl ester (CRBOME) , diesel - CRBOME blends and diesel – biodiesel – kerosene blends were measured as per IS-Standards (IS:1448). Relative density at 15^{0}C was found out as per Bureau of Indian Standards (IS: 1448, P: 32:1992). Kinematic viscosity (cSt) was calculated from time units as per standards. Isothermal Bomb calorimeter was used to determine gross calorific value as per Bureau of Indian Standard (IS: 1448, P: 10: 1984). Flash point and fire point of test samples were found out by using Pensky Martin flash and fire point as per standards.

2.1: Properties of RBOME and its blends with diesel oil and kerosene

Table II: shows characteristic fuel properties such as viscosity, density, specific gravity, flash point and fire point of diesel oil, CRBO, CRBOME and its blends with diesel and blends of CRBOME, diesel oil, and domestic kerosene in different proportions. It reveals that, it is possible to reduce the viscosity, specific gravity, flash point and fire point of CRBO by transesterifying it.

III. RESULTS AND DISCUSSION

3.1: Effect of viscosity

Viscosity of fuel is an important transport property because it determines flow characteristics when a fuel flows through fuel flow line, injector nozzle, and orifices. Figure 1 shows kinematic viscosity of diesel oil, CRBO, B100,B20, B40, B60, B80, kerosene, B20 K5, B40 K10, B60 K15, and B80 K20 respectively .Viscosity of B20, B40, B60, B80, B100 and CRBO were observed to be 2.93 cSt, 3.37 cSt, 3.93 cSt, 4.98 cSt, 6.08 and

32.15 cSt respectively as shown in Figure 1. Similarly, kinematics viscosity of B20 K5, B40 K10, B60 K15, B80 K20 and kerosene are found out and represented in Figure 1. Viscosity of CRBO is higher than all samples. Figure 1 also indicates that kerosene has least viscosity (1.12 cSt). High viscosity of CRBO and B100 would be attributed to molecular composition and structure, greater carbon chain length and reduced number of double bonds than those of diesel oil. Results indicated that viscosity B100 was 2.32 times of diesel oil. B20 and B20K5 were found to have viscosity 1.12 and 1.11 times than diesel oil. Figure 1 indicates that viscosity increases with the increase in percentage of methyl esters in the blends. B20 and B20K5 test samples have lower viscosity than other test blend samples. High viscosity of CRBO and B100 leads to poor atomization of fuel spry which results in large droplet size. This leads to poor mixing of fuel and air which in turn results in incomplete combustion. Finally, it results loss of power and thermal efficiency.

3.2: Specific gravity

The density of fuel is correlated with particulate emissions. Figure 2 shows specific gravity of diesel oil, CRBO, B100, B20, B40, B60, B80, kerosene, B20 K5, B40 K10, B60 K15 and B80K20. B80 and B80K20 have higher specific gravity (0.86) which is next to B100 (0.875). Figure 2 also shows that specific gravity increases with the increase in the proportion of methyl ester in the blends. From Figure 2, it was observed that B20 and B20K5 have minimum specific gravity (0.825) which is very close to that of diesel oil. CRBO has highest value of specific gravity (0.91) which was reduced to B100 (0.875) by transesterification process

Table II: Characteristic fuel properties of diesel and RBO-ME and their blends

Fuel Property	Diesel	CRBO	B100	B20	B40	B60	B80	Kerosene	B20 K5	B40 K10	B60 K15	B80 K20
Kinematic viscosity (cSt)	2.62	32.15	6.08	2.93	3.37	3.93	4.98	1.12	2.90	3.09	3.35	3.67
Specific Gravity	0.81	0.91	0.875	0.825	0.835	0.85	0.86	0.78	0.825	0.84	0.85	0.86
Gross calorific value (MJ/kg)	43	40	41	43	42	42	41	43	43	42	42	41
Flash point(^{0}C)	55	235	183	84	91	95	139	52	65	78	95	118

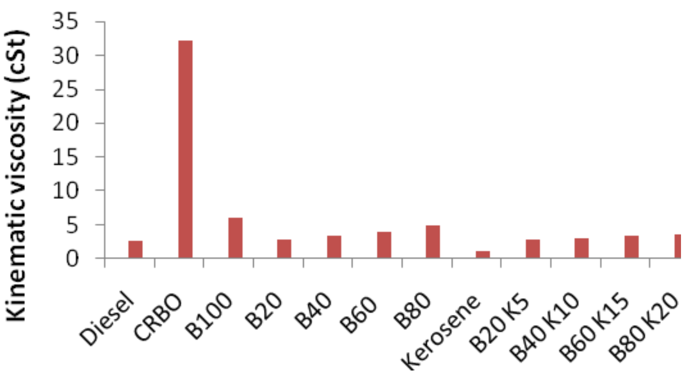

Figure 1: Kineatic viscosity of Diesel,CRBO, kerosene and all test blend samples

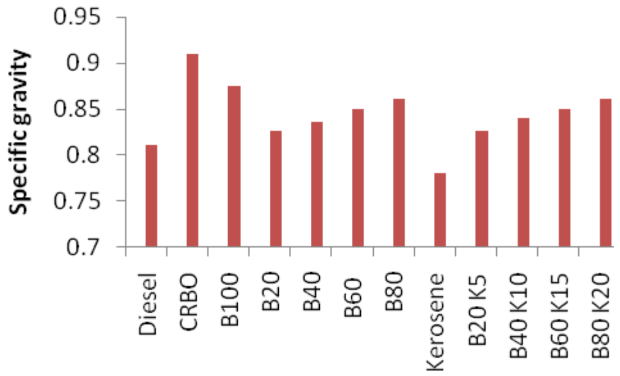

Figure 2: Speific graity of Diesel,CRBO, kerosene and all test blend sample

3.3: Heat of combustion (Gross calorific value in MJ/kg)

Figure 3 shows gross heat of combustion of diesel oil, CRBO, B100, B20, B40, B60, B80, kerosene, B20 K5, B40 K10, B60 K15 and B80K20 respectively. Calorific value of B20, B40, B60, B80, B100 were observed to be 43 MJ/kg, 42 MJ/kg, 42 MJ/kg, 41 MJ/kg, 41MJ/kg respectively as shown in **Figure 3**. Similarly, calorific value of diesel and kerosene are found out and presented in **Figure 3.** It was observed from the **Figure 3** that gross heat of combustion of B100 and CRBO are lower than diesel oil. The lower gross heat of combustion could be attributed to the presence of fewer H_2 atoms in the molecule. Esterification of crude rice bran oil into methyl ester increases its gross heat of combustion but, it was still much less than that of diesel oil. The gross heat of combustion of diesel – RBOME blends was found to be close to that of diesel oil. Figure 3.shows that B20 has high calorific value (43 MJ/kg), and B100 has lowest calorific value (41 MJ/kg). Figure 3 also indicates that replacing diesel oil by kerosene (i.e.5%, 10%, 15% and 20%) does not have negative impact on gross heat of combustion. There is no gain or loss of gross heat of combustion by replacing certain percentage of diesel oil by kerosene.

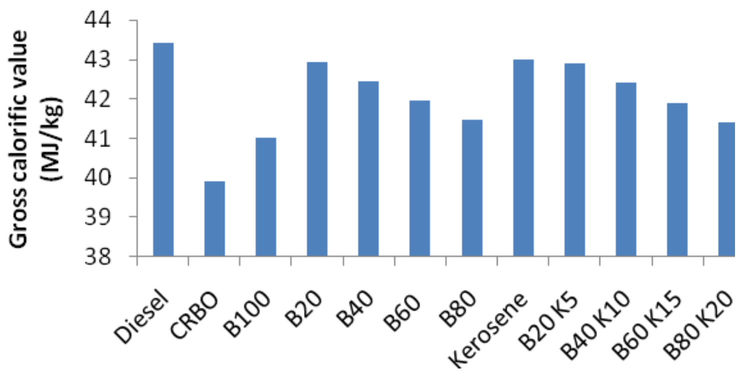

Figure 3: Gross calorific value of Diesel,CRBO, kerosene and all test blend samples

3.4: Flash point

Flash point of a fuel indicates the temperature at which the fuel ignites when exposed to a flame. Figure 4 shows the flash point of diesel oil, CRBO, B100, B20, B40, B60, B80, kerosene, B20K5, B40K10, B60 K15 and B80K20 respectively. Flash point of B20, B40, B60, B80 and B100 were observed to be 84 ^{0}C, 91^{0}C, 95^{0}C, 139^{0}C and 183^{0}C respectively as shown in Figure 4. Similarly, flash point of B20 K5, B40 K10, B60 K15, and B80 K20 respectively are found out and presented in Figure 4. Esterification of crude rice bran oil was found to reduce its flash point. Figure 4 indicates that the flash point increases with the increase in proportion of ester within the blends. Figure 4 also shows that B100 has higher flash point (183^{0}C) which is safe for transport purpose. B20K5 has lower flash point (65^{0}C), which is very closer to diesel oil. Figure 4 indicates that there is a marginal decrease in flash point when diesel oil is replaced by 5%, 10% and 20% kerosene in B20, B40 and B80 blends.

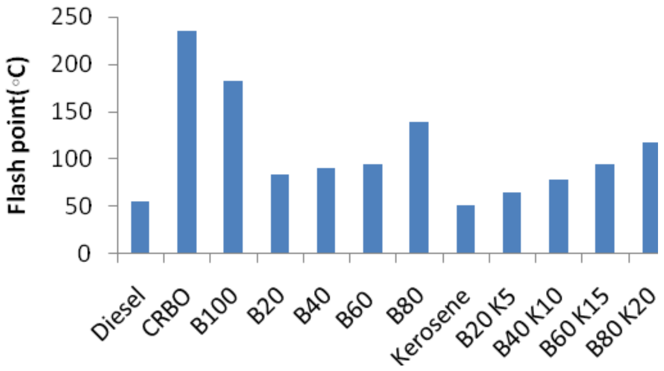

Figure 4: Flash point of Diesel,CRBO, kerosene and all test blend samples

IV. CONCLUSION

On the basis of the observed fuel properties, the following conclusions may be drawn:

[1] The use of RBOME (Rice bran oil methyl ester) as diesel fuel mainly depends on its characteristic fuel properties. Fuel properties such as viscosity and flash point of Crude rice bran oil were found to be far greater than those of diesel oil and therefore, make it unsuitable for use as fuel in diesel engines.

[2] Three–stage transesterification of Crude rice bran oil into methyl ester brought the properties closer to those of diesel oil. The viscosity of RBOME was within the recommended limit.

[3] Blending the RBOME with diesel oil further brought the properties closer to those of diesel oil. RBOME may be blended with diesel oil because the blends seem to have some of the major fuel characteristics, such as viscosity, and heat of combustion were close to those of diesel oil. The use of blend of diesel with RBOME may be restricted to lower proportions of RBOME as the higher proportions of RBOME tend to deviate further from diesel in their properties.

[4] Replacing diesel oil by kerosene (i.e.5%, 10%, 15% and 20%) in B20, B40, B60 and B80 does not have a negative impact on fuel properties such as kinematic viscosity, specific gravity, gross heat of combustion and flash point. There is no gain or loss in fuel properties by replacing certain percentage of diesel oil by kerosene.

[5] The price of biodiesel blends can be reduced by replacing diesel oil (up to 20%) by kerosene in the blends of biodiesel.

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