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Non Conventional Energy Source For Small Capacity Diesel Engine From High FFA Rice Bran Oil

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Abstract : *Energy is an essential requirement for economic and social development for any country but, with advent of industrial revolution and sky rocketing of petroleum fuel costs in present day has led to growing interest in alternative fuels which can be produced from locally available resources within the country such as alcohol, biodiesel, vegetable oils etc in order to provide a suitable substitute to diesel. Increased environmental awareness and depletion of resources are driving industry to develop viable alternative fuels from renewable resources that are environmentally more acceptable. Vegetable oil is a potential alternative fuel. The most detrimental properties of vegetable oils are its high viscosity and low volatility, and these cause several problems during their long duration usage in compression ignition engines. The most commonly used method to make vegetable oil suitable for use in CI engines is to convert it into biodiesel. India is the highest producer of rice bran oil in the world.The estimated yield of crude Rice Bran Oil (RBO) is about 8.1 lakh tons of which only 50% is of edible grade, 50% of the total available rice bran oil is left unutilized due to the presence of active lipase in bran which hydrolyses the triglyceride to fatty acids and glycerol, as a result the Free Fatty Acid (FFA) content increases making it difficult to refine, due to the presence of tightly associated wax and lack of economic stabilization methods most of the bran is used as animal feed or for industrial application. This study targets at finding the effects of the engine parameters to compare the performance of diesel and rice bran biodiesel blends. Rice Bran (RB) blends were found to be substitute for diesel fuel. By using blends the engines shows excellent performance properties., also Brake Thermal Efficiency (BTHE), Brake Specific Fuel Consumption (BSFC) and Brake Specific Energy Consumption (BSEC) shows remarkable results when tested.*

I INTRODUCTION

Biodiesel (BD) is obtained through trans esterification of vegetable oil, animal fat or waste cooking oil (comprised mainly of acyl glycerol and free fatty acid) with monohydric alcohol to give the corresponding mono alkyl ester. The most commonly used alcohol is methanol, and the corresponding fatty acid methyl ester (FAME) is often referred to as BD, which can be used as neat or blend with conventional fossil derived petro diesel (PD). A blend of BD (20%) in PD is the most popular[1] brand as B20. BD is technically competitive with PD and requires practically no changes in the fuel distribution infrastructure. Although BD faces some technical challenges, such as reducing NO_x exhaust emission, improving cold flow properties, and enhancing oxidative stability, BD has advantages over PD such as the reduction of most exhaust emissions, biodegradability, a higher flash point, greater lubricity, and availability from renewable sources. BD has higher oxygen content than PD and its use in diesel engine has shown great reductions in emission of particulate matter (PM), carbon monoxide (CO), sulfur, poly aromatics, hydrocarbons (HC), smoke and noise. In addition, burning of vegetable oil based fuels does not contribute to net atmospheric CO_2 levels because such fuel is made from agricultural materials, which are produced via photosynthetic carbon fixation. Therefore, BD is one of the alternative fuels regarded as environment friendly.

II RICE BRAN OIL

Rice (*Oryza sativa* Linn) bran is a byproduct, obtained from the outer layers of the brown (husked) rice kernel during milling to produce polished rice. Whole rice grain comprises (dry weight basis) Endosperm, 73-74; Hull, 21; Bran, 7.46-8.5; and Embryo, 2-3%. Rice bran comprises percarp, tegmen (layer covering endosperm), aleurone and sub-aleurone and sub-aleurone. The rice bran contains oil in the range of 15-23%, in Japan, where it is popularly known as “heart oil” as it keeps plasma cholesterol at low level and decreases the risk of cardiovascular diseases. However, crude RBO has been difficult to refine because of its high FFA content, unsaponifiable matter and dark color. Based on the quality of bran, a wide range of variations in the composition of acylglycerol can be possible.

FFA occurs in most oils extracted from various rice bran samples. RBO contains[2] relatively lower content of triacylglycerol compared to other vegetable oils and high contents of partial glycerides, glycolipids, wax esters and unsaponifiablel. Wax in RBO is especially difficult to remove completely. The presence of residual wax imparts haziness to the oil, especially in colder climates. This along with the darker color of the oil, have been responsible for the poor acceptance of RBO by consumers. Another major drawback in producing edible grade RBO from crude oil is its high FFA content. Freshly milled rice bran has a short shelf life because of the decomposition of lipids into FFA by lipases,

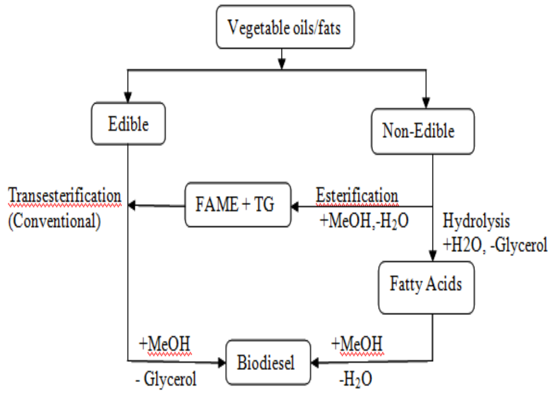
The advantages of direct use of raw vegetable oil as diesel fuel[3] are: 1) liquid nature-portability, (2) heat content (80% of diesel fuel) (3) ready availability, (4) renewability and (5) economic viability. However, the use of raw vegetable oil as a fuel in compression ignition engines has shown problems of higher viscosity, lower stability and lower volatility. The content of partial glycerides, wax ester, steryl ester, unsaponifible matter, polar lipid in the oil and degree of saturation of glycerides are major factors responsible for the high viscosity of raw vegetable oil. The viscosity of crude RBO is 2-3 times that of other vegetable oils.With vegetable oil as the fuel, problems appear only after the engine has been operated on extended periods of time, resulting in severe engine deposit, piston ring sticking, injector coking, thickening of the lubrication, and eventual engine failure. Deterioration and incomplete combustion are other major problems associated with vegetable oil as biofuel. Diesel used in diesel engines contains higher amounts of aromatics and sulphur, which cause environmental pollution.Properties of biodiesel are similar to mineral diesel and can be used in conventional diesel engines without significant modifications[4,5]. Biodiesel is synthesized from direct transesterification of vegetable oils, where the corresponding triglycerides react with a short-chain alcohol, usually methanol in the presence of a catalyst. RBO extracted from the bran immediately after the milling of rice is high in FFA (6-8%).Physico chemical properties of RBO are: specific gravity, 0.916-0.921; refractive Index $^{25°C}$, 1.470-1.473; acid value, 4-120; saponification value, 181-189; iodine value, 99-108; peroxide value, 2 max; and unsaponifiable matter, 3-5%.

III MATERIALS AND METHODS

Industrial grade RBO was procured from a local oil market. Diesel was purchased from the nearby petrol pump. All reagents used were of AR Grade.

IV EXPERIMENTAL PROCEDURE [6]

Acid number (85) of RBO was evaluated by ASTM D-664 to quantify the FFA content (42.5%) in oil. Due to very high FFA, RBO was converted into its methyl ester by the two-stage process (Fig.1). In the first stage, RBO was reacted with CH_3OH in presence of an acid catalyst (H_2SO_4) to convert FFA into fatty ester. A specified amount (1000 g) of RBO was taken in a round bottom flask and heated up to 60-65°C. In a separate flask, CH_3OH (950 g) and H_2SO_4 (22 g) were taken and properly mixed and then transferred to the round bottom flask containing RBO. The mixture was stirred for 4 h and maintained at 60°C. It was allowed to cool overnight without stirring. When acid number of the mixture reached less than 1, the second stage was started. During this stage, mixture (1000 g) obtained from the first stage was taken in a round bottom flask and heated up to 60°C. Methanol (200 ml) and KOH (4.5 g) were properly mixed in other flask and then introduced into the round bottom flask containing the mixture from first stage[7,8]. The mixture was stirred vigorously for 2 h and then allowed to cool overnight. Glycerol was separated by adding warm water at 60°C to the mixture. Glycerol and soap formed during the process settled down at the bottom. Top layer containing RBO methyl ester (91 %) was removed with the help of a separating funnel and washed two times with water and dried. Physico-chemical characterization indicated kinematic viscosity of RBO methyl ester (RBOME) near to that of diesel



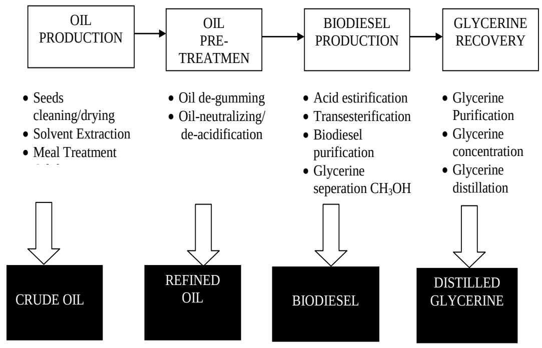
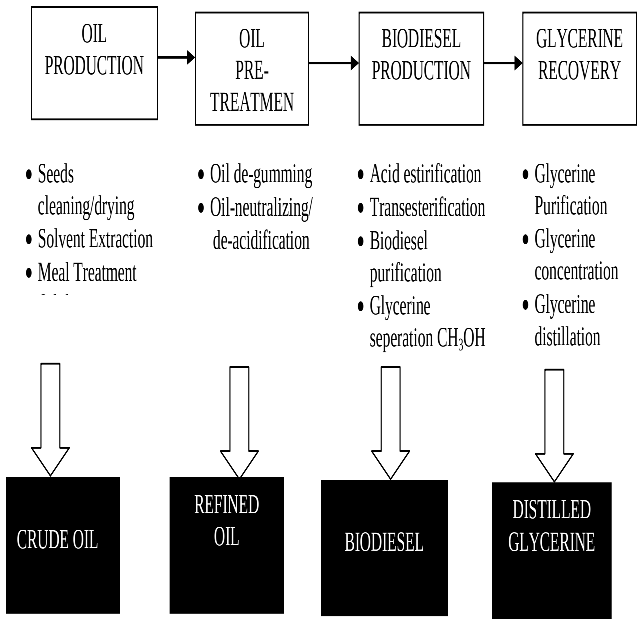


Fig 2: Production of Bio diesel from Rice Bran



V RESULTS

Properties of biodiesel [9]

All properties of ricebran oil biodiesel (Table: 1) were in agreement with ASTM standards, except kinematic viscosity, which was slightly higher than the upper limit

. This may result in slight increase of BSFC because of poor atomization of fuel spray and less accurate operation of fuel injectors. A high value of flash point indicates that the fuel is safe. Pour point was also sufficiently low, indicating that the performance of ricebran oil biodiesel will be satisfactory in cold climates too.

Properties	**Diesel**	**Rice bran oil biodiesel**
Calorific Value, kJ/kg	44585	41382
Density, g/cm^3 at room temperature	0.831	0.872
Kinematic viscosity @ 40□ C, mm^2/s	3.21	4.93
Acid No., mg.KOH/g	0.18	0.57
Pour Point, □ C	-17	-4
Flash Point, □ C	76	143
Copper strip corrosion	1A	1A
Ramsbottom carbon residue, % wt	0.05	0.023
Sulfur, ppm	340	11
Lubricity (HFFR Test)	450	293
Cetane number	47.2	53.6

VI ENGINE TEST

Kirloskar SV1 (661 cc), single cylinder, four stroke, vertical[10], water cooled, high speed compression ignition diesel engine (Fig. 3) was used and mounted on the ground. The test engine was directly coupled to an eddy current dynamometer with suitable switching and control facility for loading the engine. Liquid fuel flow rate was measured on volumetric basis using a burette and a stopwatch. Engine specifications were as follows: bore & stroke, 87.5 mm x 110 mm; compression ratio, 17.5: 1; speed, 1800 rpm; fuel timing, 27° by spill (btdc); clearance volume, 37.8 cc; and rated power, 8 hp.

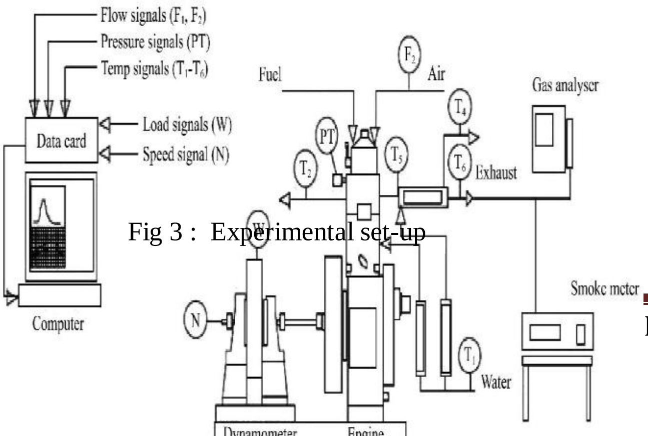


Fig 3 : Experimental set-up

Where, F_1 and F_2 – are flow sensors for fuel and air; W- load sensor; $T_1 – T_6$- are temperature sensors; P&T – are cylinder pressure and injection pressure sensor; N – is engine speed.

VII TESTING PROCEDURE

Engine testing[11] was done in a laboratory at a constant temperature. Engine was started and warmed-up at low idle, long enough to establish the recommended oil pressure, and was checked for any fuel, oil leaks. After completing warm-up procedure, engine was run on no-load condition and speed was adjusted to 1800 rpm by adjusting fuel injection pump. Engine was run to gain uniform speed, after which it was gradually loaded. Experiments were conducted at different torque levels (0, 8, 16, 24, 12 and 32 Nm). For each load condition, engine was run at a minimum of 10 min. Simultaneously, engine exhaust emissions were also determined.

Brake Thermal Efficiency (BTE)

BTE was maximum (28.1%) for B20 at load of 12 kgf, followed by B0 (26.8%) and B100 (26.1%). B100 has higher oxygen content than B0, but lower calorific value (43.3 MJ/kg v/s 45 MJ/kg in present study). B20 had a slightly lower calorific value than B0, but better oxygen content than B0, thus giving a better performance[12].

Brake Specific Fuel Consumption (BSFC)

BSFC was found to be decreasing with respect to brake power However, increasing the load beyond 9 kgf did not affect the parameter much. B100 exhibited a maximum BSFC of 0.5378 (kg/kWh) at a load of 3 kgf. Further, BSFC of B20 was 0.38, 6.51, 0.57, 1.75 and 2.86% higher than B0 at loads of 3, 6, 9, 12 and 15 kgf respectively. Since calorific value of B100 is slightly less than B0 (3.92% lower), these deviations are relatively less. Low calorific value, high density and viscosity of biodiesel are responsible for higher consumption of biodiesel and its blends for the same power developed.

VIII DISCUSSION

The power developed by engine at varying load for diesel and biodiesel suggests that maximum power is higher in case of diesel (3.911 kW) than biodiesel (3.257 kW). This is primarily because of less heating value of biodiesel as compared to diesel. Variation of fuel consumption rate for diesel and biodiesel of RBO suggests that fuel flow rate is marginally higher in case of RBO biodiesel than diesel. Higher density of biodiesel leads to more discharge of fuel for the same displacement of the plunger in the fuel injection pump, thereby increasing fuel consumption rate. Brake specific fuel consumption (BSFC) is higher for RBO than diesel at the entire brake load, because of less heating value and more consumption of RBOME as compared to diesel in the engine. BSFC for RBOME and diesel are as follows: minimum load, 0.816, 0.683; and at maximum load, 0.455, 0.367 kg/kWH.

Since, both the fuels have different calorific values, viscosity and density, BSFC is not a reliable tool to compare the fuel consumption per unit power developed. A better approach is to compare the two fuels on the basis of energy required to develop unit power output, known as brake specific energy consumption (BSEC). The BSEC corresponding to maximum load for diesel was 16.311 kJ/kWh whereas for biodiesel it was 18.603 kJ/kWh, which suggests that energy required by biodiesel to develop unit output is more in comparison to diesel.

IX CONCLUSIONS

Biodiesel made from high FFA RBO using a two-stage formulation process had viscosity and density similar to diesel. Calorific value of biodiesel was around 7.31 % lower that of diesel. Flash point of biodiesel is quite high as compared to diesel making it safer to store and transport. Sulfur in biodiesel is very low as compared to diesel and is an important feature in term of reduction of SO_2 from the exhaust emission. The HFFR test suggests that lubricity of biodiesel in comparison to diesel is higher. Cetane number of biodiesel is also higher than diesel. Biodiesel was used as a fuel in an unmodified, small capacity diesel engine. The power developed from the engine with biodiesel as a fuel was 4% lower as compared to diesel, because of lower heating value of biodiesel. BSFC and brake specific energy consumption were also higher due to same reason. BTE was higher in diesel as compared to biodiesel. Smoke opacity was lesser of biodiesel than diesel making it more environmental friendly fuel. The study suggests that it is possible to convert high FFA RBO into biodiesel, which has similar properties to diesel and can be used to fuel an existing unmodified diesel engine without any difficulty. Thus it was concluded that B20 rice bran based biodiesel can be a suitable feedstock for biodiesel industry. Performance characteristics of B20 (BSFC, BTE, EGT and VE) were quite close to petroleum diesel. Thus, a 20% blend of Rice Bran oil biodiesel can be safely used with petroleum diesel without significantly affecting its fuel properties and performance.

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