"BIODIESEL PRODUCTION AND EVALUATION OF PERFORMANCE AND EMISSION CHARACTERISTICS OF SAL SEEDS"

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Abstract : Inflation in fuel prices and unprecedented shortage of its supply has promoted the interest in development of the alternative sources for petroleum fuels. The present paper discuss with the various phases of production of bio-diesel from Sal seeds. The phases of shelling, milling, extraction of seed oil and transesterification are discussed. The results were compared with diesel fuel, and the selected Sal seed oil fuel blends (10%, 20%, 30% and 100%). The experimental results shown that B10 has properties nearer to Diesel which can be used as fuel for vehicle. The engine performance parameters such as specific fuel consumption, Brake Thermal Efficiency and Exhaust Emission (CO, SO_x, HC, and NO_x) were recorded. The exhaust gas emissions are reduced with increase in biodiesel concentration. The experimental results proved that the use of biodiesel in compression ignition engine is a viable alternative to diesel. From the comparison of results, it is inferred that the engine performance is improved with significant reduction in emissions for the chosen oils without any engine modification.

Index terms: Biodiesel, Sal seeds, Transesterification.

1. INTRODUCTION

As the fossil fuels are depleting day by day, there is a need to find out an alternative fuel to fulfill the energy demand of the world. Biodiesel is one of the best available sources to fulfill the energy demand of the world. The petroleum fuels play a very important role in the development of industrial growth, transportation, agricultural sector and to meet many other basic human needs. However, these fuels are limited and depleting day by day as the consumption is increasing very rapidly. Moreover, their use is alarming the environmental problems to society. Hence, the scientists are looking for alternative fuels. India is importing more than 80% of its fuel demand and spending a huge amount of foreign currency on fuel. Biodiesel is gaining more and more importance as an attractive fuel due to the depleting nature of fossil fuel resources [Syed Ameer Basha, (2008)]. Recent fluctuations in the price of petroleum fuels and the economic environment have sparked renewed interest in alternative liquid fuels, such as ethanol and biodiesel. The success and sustainability of a biodiesel production facility, especially a small-scale facility, depend on the cost of the feedstock used [C.L. Butts, (2009)]. The most popular petroleum fuels in India are gasoline and diesel used as motor fuels in spark ignition and compression ignition engines respectively .Amongst them, diesel engines have proven their utility in the transportation and power sectors due to their higher efficiency and ruggedness and hence play a pivotal role in rural as well as urban Indian economy. Sal seed oil as a potential feedstock for biodiesel production which can considerably increase the feedstock availability. However, it has a dominant penetration in states like Odisha, Chattishgarah, Madhya Pradesh, Maharashtra etc. The annual estimated production of Sals seeds is around 1.5 million tonnes and the sal seed oil or fat production is around 0.18 million tonnes a year [Chauhan B.S, (2010)]. In the recent past, the crude oil prices have increased immensely and the fossil fuels are depleting. Global warming has become a global concern, which is highly contributed by the emissions of fossil fuel combustion products. Bio-fuel has emerged as an alternative fuel for petroleum due to their agricultural origin, are able to reduce net carbon dioxide and carbon monoxide emissions. Biodiesel is a diesel-equivalent processed fuel derived from biological source, which can be used directly in IC-engine. Moreover it is biodegradable and non-toxic and it possesses low emission profile. It also enhances the life of diesel engine by providing more lubrication, resulting in reduced premature wearing of engine components [Kishor Kumar S, (2018)].

2. METHODOLOGY

Step by step procedure of production of Sal seed biodiesel is given below

2.1 Extraction of seed oil

The extraction of oil from Sal seed is done by using a method called mechanical expeller. Extraction requires passing the seeds through a screw crusher, generally called expeller, i.e. Screw Oil Expeller. The oil is then filtered to make it clean enough for processing.

Fig. 1 Deshelling of Sal seed

Fig. 2 Oil Expeller

Fig. 3 Sal seed oil

2.2 Determination of FFA content of seed oil

The fatty acid is a Carboxylic acid, with a long aliphatic chain, which is either saturated or unsaturated. The seed oil sample of 1 ml is taken in a flask and 10 ml of iso-propyl alcohol is added (seed oil : iso-propyl alcohol is always maintained in the ratio of 1:10). 2 drops of Phenolphthalein indicator is added to the mixture of seed oil and iso-propyl alcohol and thoroughly mixed. This mixture is titrated against a standard solution of Sodium Hydroxide (NaOH). On the completion of titration, the colour of the solution changes from colourless to light pink. The amount of NaOH consumed is noted to calculate the Free Fatty Acid (FFA) content of the scum. The FFA content of the scum is calculated by the following formula

$$\text{FFA Content} = \frac{(28.2 * \text{Normality of NaOH} * \text{ml of NaOH consumed})}{\text{Weight of the oil}}$$

If the FFA content is below 4, a single stage of production of biodiesel can be carried out i.e the Trans-esterification. If the FFA content is greater than 4, a two stage production has to be carried out for the production of biodiesel, i.e acid-esterification to reduce to FFA content below 4 and trans-esterification

2.3 Acid Esterification

Acid-esterification is the general name given to the chemical reaction in which two reactants (typically an alcohol and an acid) form an ester as the reaction product.

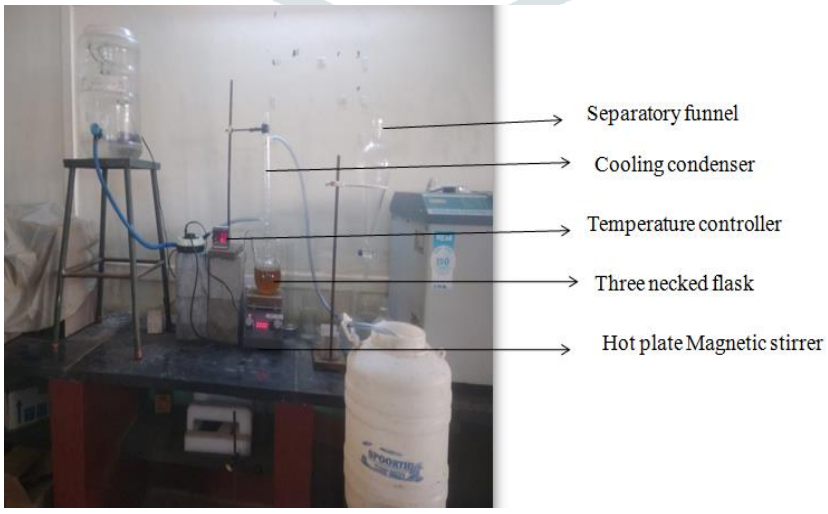


Fig. 4: Experimental setup

750 ml of seed oil is heated to about 60^0 on a hot plate magnetic stirrer and it is transferred to a clean and dry three necked flask.70 ml of Methanol and 1.5 ml of H_2SO_4 is added and stirred at a constant speed of 800 rpm for 2 hours.

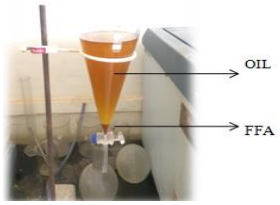


Fig. 5 Separation of FFA layer

After the completion of reaction, the solution is allowed to cool down and then transferred to a Separatory funnel and allowed to cool down for 12 hours. The formation of layers takes place, in which the top layer formed is the processed oil, which is brown in colour and the lower layer is the Free Fatty Acid which has to be drained out, separating it from the supernatant processed seed oil. The processed seed oil is then tested for Free Fatty Acid. The resulting FFA was found to be again more than 4, hence, the seed oil was again used to carry out the acid esterification process. Again the processed seed oil is tested for Free Fatty Acid. Since resulting FFA was found to be 2 (less than 4), the seed oil was used to carry out the trans-esterification process.

Table.1: Weight of NaOH for transesterification

FFA	NaOH (gm)
0	3.5
1	4
2	5.5
3	6.5
4	7.5

2.4 Transesterification

Transesterification is the process of exchanging the alkaly group of an ester compound by another alcohol. These reactions are often catalyzed by the addition of an acid or a base. The processed oil is transferred to a three necked flask and is kept on a hot plate magnetic stirrer, heated to 60^0. After the temperature reaches to 60◦, 150 ml of Methanol and 5.5 gm of NaOH are mixed in a beaker and then added to the three necked flask, which is kept in a constant stirring condition at a speed of 800 rpm. The reaction is allowed to proceed for duration of 2 hours. After the reaction is completed, the solution is allowed to cool down. Upon cooling, it is then transferred to a Separatory funnel, where it is allowed to settle down for a duration of 12 hours. The separation of layers takes place, where the upper layer is the biodiesel which appears brownish in colour. The lower layer is the Glycerin, an unwanted product that is separated from the biodiesel, by draining it into a beaker.

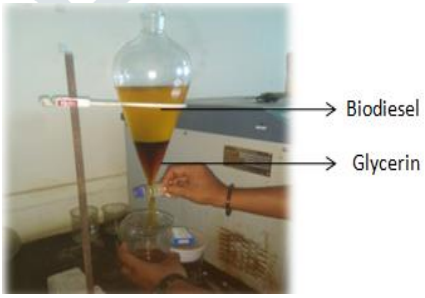


Fig. 6: Formation of layer

The biodiesel is then washed with warm water (60◦) in order to remove the methanol present in the biodiesel. The biodiesel has to be washed till the water used does not change colour after the wash. The biodiesel is then heated to a temperature of 100^0 to remove any traces of water content present in it. The biodiesel is then stored for further tests to be conducted on it.

Fig. 7: Water washing

Fig. 8: Biodiesel and Glycerin

3. RESULTS AND DISCUSSION

3.1 Properties of Sal seed Biodiesel

Different properties of biodiesel like Density, Kinematic Viscosity and Calorific value were tested using hydrometer, viscometer and bomb calorimeter respectively. Sal seed biodiesel was blended with conventional diesel in the following proportions:-

B10 10% Biodiesel + 90% Diesel

B20 20% Biodiesel + 80% Diesel

B30 30% Biodiesel + 70% Diesel

Table 2: Properties of Biodiesel

PROPERTIES	DIESEL	B10	B20	B30	B100
VISCOSITY (cSt)	3.2	3.18	3.47	3.79	5.48
DENSITY (kg/m^3)	826	830	839	846	853
CALORIFIC VALUE (KJ /kg)	39311	38760	37780	36820	32764

3.1.1 Variation of Kinematic Viscosity for Different Biodiesel-Diesel Blends

Viscosity is one of the most significant properties of biodiesel since it plays a vital role in fuel injection process of diesel engine. If the viscosity is high it affects atomization process because of which effective mixing of fuel with air will not takes place and it in turn causes incomplete combustion . Viscosity will be high for those oils having longer chain length of fatty acid and is less for those oils having more amount of unsaturated fatty acid. From table 2, it can be observed that Sal seed Biodiesel has highest viscosity of 5.48 cSt. Among blends B10 has viscosity nearer to diesel value i.e. 3.18 cSt.

3.1.2 Variation of Density for Different Biodiesel-Diesel Blends

Density of Biodiesel depends upon molecular weight. Since the density of Sal seed biodiesel is more than conventional diesel fuel, the density of different blends increases with the increase in biodiesel percentage and same can be observed in table 2. Sal seed Biodiesel has maximum density of 853 kg/m^3. Among blends B10 has density close to Diesel value i.e. 830 kg/m3.

3.1.3 Variation of Calorific Value for Different Biodiesel-Diesel Blends

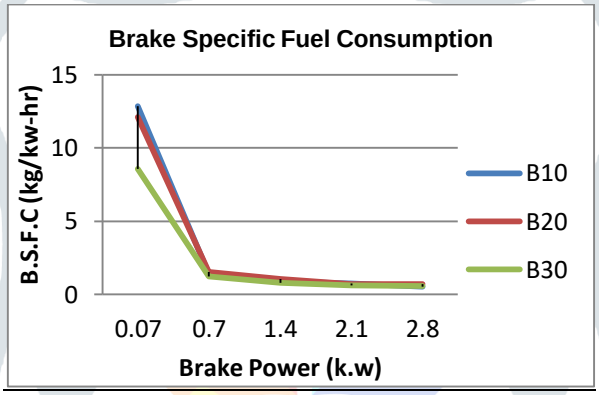
Calorific value of fuel is one of the important parameter that determines efficiency of an engine. Higher the calorific value of a fuel, larger amount of heat will be released which increases the efficiency of the engine. From table 2, it can be observed that as biodiesel percentage in blends increases there is a decrease in calorific value. It is because of the reason that since Biodiesel is an oxygenated fuel; its calorific value is less compared to diesel. Diesel has a highest calorific value 39311 kJ/kg and among blends B10 has calorific value nearer to diesel value 38760 kJ/kg.

3.2 Performance Evaluation

In IC engine, the thermal energy is released by burning the fuel in the engine cylinder. The combustion of fuel in IC engine is quite fast but the time needed to get a proper air/fuel mixture depends mainly on the nature of fuel and the method of its introduction into the combustion chamber.

3.2.1 Brake Specific Fuel Consumption (B.S.F.C)

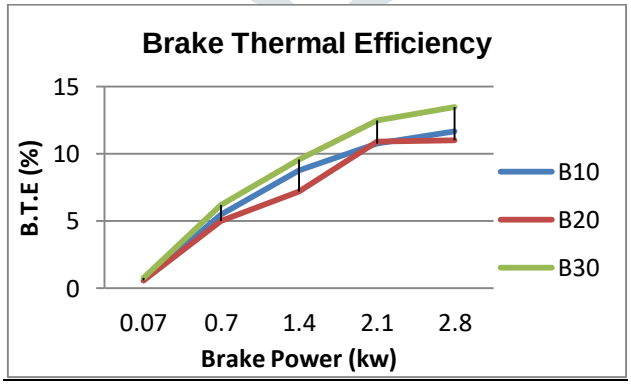
Brake Specific Fuel Consumption (B.S.F.C.) is the fuel consumed by the engine per unit of power output or produced. It is desirable to obtain a lower value of BSFC meaning that the engine used less fuel to produce the same amount of work.



For fuel tested, decrease in B.S.F.C. was found with increase in brake power. It can be seen from this graph that as Brake Power increases, B.S.F.C. decreases to minimum at full load condition. By observing related results at full load engine condition, the value of B.S.F.C. for B10 blend is minimum.

3.2.2 Brake Thermal Efficiency

Brake Thermal Efficiency is the ratio of the power output of the engine to the rate of heat liberated by the fuel during the combustion.



It is observed that the brake thermal efficiency is low at low values of BP and increases with increase of BP for all blends of fuel. For a blend of 30% the brake thermal efficiency is high at low BP values when compared with other blends of fuel. Hence at the blend of 30%, the performance of the engine is good.

3.3 Emission Characteristics

Table 3: Emissions with Biodiesel

Fuel	Exhaust Emission (ppm)			
	CO	HC	SO_X	NO_X
DIESEL	0.063	10	5	649
B10	0.051	11	7	788
B20	0.073	19	5	802
B30	0.015	9	2	821

The above table shows that all emissions with biodiesel are lower than diesel except NOX. NO*x* emissions will increase when using biodiesel. This increase is mainly due to higher oxygen content for biodiesel. The higher of NOX emission could be reduced either by the use of catalytic converter.

The above analysis of biodiesel shows that the reduction in CO emission is about 19% with B10 and 76% with B30 use on per litre combustion basis. CO emissions reduce when using biodiesel due to the higher oxygen content and the lower carbon to hydrogen ratio in biodiesel compared to diesel.

4. CONCLUSION

The Sal seed oil was successfully extracted from the seeds. The oil thus extracted was made to undergo the transesterification process and conditioned. Nearly 20% of Glycerin is produced as byproduct. Bio-diesel properties are then compared with neat diesel. The blend B10 properties were close to diesel properties. Calorific value of B10 is more compared to B20 and B30. Reduced viscosity which in turn increases the fuel automization resulting in good combustion. From the performance evaluation, it is observed that the performance of C.I engine has increased by using blended biodiesel in comparison with pure diesel. From this study it is observed that the blended biodiesel can be used as an alternate fuel for the C.I engine without any engine modification. It is inferred, from the results that the brake thermal efficiency is higher for B30 and less fuel consumption for B10.

From the emission characteristics, it is concluded that biodiesel and its blends as a fuel for diesel engine have better emission characteristics compared with diesel as follows:

(1) CO emissions are less compared with diesel

(2) NOx emissions for biodiesel and blended fuel are slightly higher than that of diesel

(3) From this analysis it can be concluded that B30 gives better performance with reduced pollution.

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