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Production of Biodiesel from Mahua Oil by Mechanical Stirring and its Performance Testing on a Diesel Engine

Ankit Malviya, Ankur Kumar Bera**, Manish Dev Pandey***, Lucky Gupta****, Praveen Gautam***** and Ashok Kumar Yadav*******

ABSTRACT

Biodiesels are fuels that are made from renewable oils that can usually be used in diesel engines without modification. These fuels have properties similar to fossil diesel oils and have reduced emissions from a cleaner burn due to their higher Oxygen content. The current and impending energy and environmental crises have revitalized the need to find more viable renewable resources. The present work investigates the production of biodiesel from mahua oil by mechanical stirring method at different molar ratio and reaction time. After that engine performance were evaluated, operated with blends of mahua biodiesel and diesel.

Keywords: *Mahua Oil; Biodiesel; Transesterification Process; Diesel Engine Performance.*

1.0 Introduction

In 2011-12, India was the fourth largest consumer in the world of Crude Oil and Natural Gas,after the United States, China, and Russia. India's energy demand continued to riseinspite of slowing global economy.

Petroleum demand in the transport sector is expected to growrapidly in the coming years with rapid expansion of vehicle ownership. While India'sdomestic energy resource base is substantial, the country relies on imports for a considerableamount of its energy use, particularly for Crude Petroleum.

There was an increase by 7.15% in production of total petroleum products, including fractioners,during 2012-13 compared to the year 2011-12.

At the same time, the indigenous consumption ofpetroleum products increased by 4.92 % during 2012-13 compared to the previous year. During the year 2012-13, consumption of petroleum products was 156.528 MMT against totalproduction of 217.736 MMT.

2.0 Production Methods of Biodiesel

The biodiesel can be produced by the following useful methods:-

- Micro-emulsions
- Pyrolysis
- Transesterification

Out of the above production methods, the transesterification is the most efficient method for the production of biodiesel from non-edible oils. In transesterification process, a triglyceride reacts with three molecules of alcohol in the presence of catalyst producing fatty acids alkyl esters and glycerol. Tranesterification is the reversible reaction so excess alcohol is added to increase the yield of alkyl esters and to allow its phase separation from the glycerol formed. The various parameters which affect the conversion of non-edible oils to biodiesel are given in Table 1.

2.1Time of reaction

It is one of the important parameter. Conversion of non-edible oil increases with the

**Department of Mechanical Engineering, Raj Kumar Goel Institute of Technology, Ghaziabad(UP), India*
***Department of Mechanical Engineering, Raj Kumar Goel Institute of Technology, Ghaziabad(UP), India*
****Department of Mechanical Engineering, Raj Kumar Goel Institute of Technology, Ghaziabad(UP), India*
*****Department of Mechanical Engineering, Raj Kumar Goel Institute of Technology, Ghaziabad(UP), India*
******Department of Mechanical Engineering, Raj Kumar Goel Institute of Technology, Ghaziabad(UP), India*
*******Corresponding Author: Department of Mechanical Engineering, Raj Kumar Goel Institute of Technology, Ghaziabad(UP), India (E-mail: ashokme015@gmail.com)*

increase in reaction time. After a certain time of reaction there is no further increase in the conversion with the increase in reaction time because of the following factors:-

a) Rate of reaction is directly proportional to the concentration of oil in the reaction mixture. The rate of reaction therefore decreases with time as the concentration of oil keeps on decreasing with time.
b) Transesterification is a reversible reaction and has an equilibrium conversion, which is independent of time. Optimum reaction time to obtain high conversion is 110-120 min

2.2 Reaction temperature

The rate of reaction is affected by reaction temperature. The reaction is conducted close to boiling point of methanol (60^0C to 70^0C) at atmospheric pressure. This reaction condition is required for the removal of free fatty acids from the oil by pre-esterification.

The maximum yield of ester is obtained at temperatures ranging from 60^0C to 80^0C at molar ratio (alcohol to oil) of 6:1. Negative effect is reported if the temperature is increased further.

2.3 Reactants ratio

Molar Ratio of Alcohol to Oil: Molar ratio of alcohol to non-edible oil is also important variable. When 100% excess methanol is used, the reaction rate is the highest.

A molar ratio of 6:1 is normally used to obtain methyl ester yields higher than 80% by weight. Higher molar ratio of alcohol to non-edible oil interferes in the separation of glycol.

Table 1: Available Potential of Tree-Borne Oilseeds (TBOs) in India

SN o.	TBOs	Seed yield (lakh tonnes)	Oil conten t (%)	Oil yield (lakh tonnes)
1.	Sal (Shorearobusta)	62.0	12	7.44
2.	Mahua (Madhuca indica)	5.2	35	1.82
3.	Neem (Azadirachta indica)	5.0	20	1.0
4.	Rubber(Hevea brasiliensis)	0.79	45	0.35
5.	Karanja(Pongamia pinnata)	1.11	27	0.30
6.	Kusum(Schleichera oleosa)	0.45	33	0.15
7.	Khakan(Salvadoraoleoides)	0.44	33	0.14

Table 2: Comparative Assessment of Physico-Chemical Properties Exhibited by Mahua Biodiesel and Mineraldiesel

S.No.	Properties	MahuaBio- Diesel	Diesel
1	Density at 15°C (g/cc)	0.87	0.8239
2	Viscosity at 40°C (cst)	4.9	2.956
3	Calorific Value(MJ/kg)	41.6	45.49
5	Oxidation Stability	>6	-

2.4 Type of catalyst & concentration

Alkali metal alkoxides are the most effective transesterification catalyst compared to the acidic catalyst. Sodium alkoxides and Potassium alkoxides are the most efficient catalysts. Trans- methylations occurs approximately 4000 times faster in the presence of an alkaline catalyst than those catalysed by the same amount of acidic catalyst.

The alkaline catalysts are also less corrosive to industrial equipments than acidic catalysts. Therefore alkaline catalysts are preferred for the process. The alkaline catalyst concentration in the range of 0.5 to 1% by weight yields 80% to 85% conversion of non-edible oil into esters. Further increase in catalyst concentration does not increase the conversion and it adds to extra costs. (2)

2.5 FFA content of the vegetable oil

FFA content signifies the free fatty acid content. Lower the FFA easier the conversion of the vegetable oil to biodiesel. Preferably FFA content must be lower than 2.5%, otherwise we have to adopt the two step tranesterification process the conversion of the vegetable oil to biodiesel.

Table 3 proposed the required quantities of Methanol and Catalyst (KOH) to mix in Non-edible oils for the production of Biodiesel

Table 3: Quantities of Methanol and Catalyst used for the Production of Biodiesel

Molar Ratio Alcohol/Oil	Quantity of Non-edible oil (gm)	Quantity of Methanol (gm)	Catalyst (KOH)		
			0.5%	0.75%	1.0%
6:1	50	11	0.25 gm	0.375 gm	0.5 gm
4.5 : 1	50	8.28	0.25 gm	0.375 gm	0.5 gm

3.0 Experimental Setup for Biodiesel Productionand Procedure

A cylindrical glass jar is taken and mixture is put inside the jar. Digital thermometer is use to take the temperature of mixture. The cylindrical glass jar is put on metallic heater and the magnetic metal piece stirrer is put into the mixture.

The magnetic stirrer mixes the mixture properly. A known quantity of Mahua oil (100 gm.) was taken inside the cylindrical glass jar and heated about 70^0C. This temperature is maintained throughout the reaction by the thermostat inside the metallic heater.

Prior to this the oil was preheated upto 110^0C to remove unwanted moisture in the oil. KOH was used as catalyst to achieve basic medium in transesterification. Catalyst was dissolved in alcohol (Methanol). The catalyst, Potassium Hydroxide (Potash) was dissolved in alcohol using a standard agitator.

Alcohol with dissolved catalyst was added toMahua oil at 70^0C and equilibrium temperature was maintained, alcohol used to vaporize during the reaction.

This reaction temperature was maintained as rate of reaction was directly proportional to temperature.

Recommended reaction time varies from 120-150 minutes. Excess alcohol is normally used to ensure total conversion of non- edible oils to its esters.

The solution was kept in separating funnel after the reaction was over. Two phases of different densities were formed during the process of transesterification.

3.1 Separation

Separation was done in separating funnel which takes 4 to 6 hours. The upper layer consisted of biodiesel and lower layer consisted of heavier glycerin with some impurities. The glycerin was heavier and it can be taken out from the bottom of beaker.

3.2 Water wash process

Biodiesel obtained contains some amount of catalyst and soap. These can be removed by gently washing it with warm water. The biodiesel was mixed with water amounting to $1/3^{rd}$ by volume of Biodiesel. It was heated gently and then the water was taken out. The biodiesel was again heated to 100-110^0C to remove any traces of water and alcohol. In this way, the biodiesel was produced.

4.0 Experimental Engine Setup and Test Procedure

A Four-stroke single cylinder diesel engine with mechanical rope brake loading was used for this study. It is a single cylinder, four stroke, vertical, water-cooled engine having a bore and stroke of 80 and 110 mm respectively. The compression ratio was 16.5 at rated speed of 1500 rpm.

It has a provision of loading through rope brake dynamometer. The inlet valve opens at 4.5^o before top dead center and closes at 35.5^o after bottom dead center the exhaust valve opens 35.5^o before bottom dead center and closes 4.5^o after top dead center. For getting the base line data of the engine first the experimentation is performed with diesel and then with blends of Mahua oil methyl ester with different blend ratio (5%, 10%,15% and 20%). at 20%, 40%, 60%, 80% and 100% load at a constant speed of 1500 rpm. A burette and a stop watch were used to measure the fuel flow rate on volume basis. The engine has run smoothly through the whole study and no major problem was reported.The engine specifications are given in Table 4

5.0 Results and Discussion

5.1 Results of biodiesel production

The three Mahua oil samples of 100 gm. each were taken. In 1st Sample, 100gm oil was mixed with 22gm Methanol and 1gm KOH and the yield obtained was 70%. In 2nd sample, 100 gm oil was taken and mixed with 22gm

Methanol and 3gm KOH and the yield obtained was 50%. In the 3rd sample, 100 gmMahua oil was mixed with 44gm Methanol and 2gm

KOH and the yield obtained was 64%.Figure 2&3 shows the variation of biodiesel yield with respect time for 6:1&4.5:1 molar ratio respectively for different percentage of catalyst (KOH).

It has been observed that the yield for 1.0% KOH is higher

Table 4: Test Engine Specifications

Make	Kirloskar
Rated power	5.2 kW @ 1500 rpm
Speed	1500 RPM
No. of cylinders	One
Compression Ratio	17.5 : 1
Bore	87.5mm
Stroke	110mm
Orifice Diameter	20mm
Method of loading	Rope Brake
Method of Starting	Crank Start

Fig 2: Time vs. Yield Graph at 6:1 Molar Ratio for Different KOH Percentage

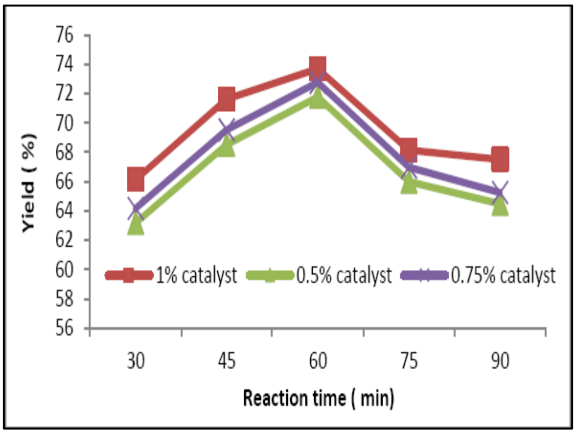
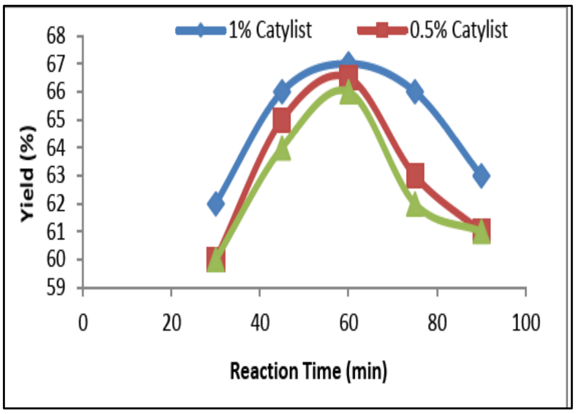


Fig 3: Time vs. Yield Graph at 4.5:1 Molar Ratio for Different KOH Percentage.



5.2 Results of engine test

The engine performance with mahua biodiesel was evaluated in terms of brake specific energy consumption and thermal efficiency at different loading conditions of the engine. Engine performance was measured using 100% Diesel, 5% MOME, 10% MOME, 15% MOME and 20% MOME only. This blend ratio was selected because it is practically viable to have this ratio because of low availability of biodiesel and also it is in line with the intention of the Government of India to blend up to 20% biodiesel with mineral diesel for the automobile sector.

5.2.1 Brake thermal efficiency

Change in BTE of blends B5, B10, B15, B20 and diesel with respect to change in load is shown in Figure 4. At no load condition, brake thermal efficiency of B5, B10, B15, B20 and diesel is same. As the load on the engine increases, brake thermal efficiency increases because brake thermal efficiency is the function of brake power and brake power increases as the load on the engine increases. At no load condition, brake thermal efficiency of B5, B10, B15, B20 and diesel is same.

At part load conditions, the brake thermal efficiency of B10 is more than diesel because mass of B10 supplied is 19.35% less than that of diesel and calorific value of B10 is also less than that of diesel. Brake thermal efficiency of B15 and B20 is almost same at part loads and is 16.67% less than diesel because of lower brake power and higher amount of fuel supplied. At full load conditions, brake thermal efficiency ofB5, B10, B15 and B20 is almost same but is less than diesel. Similar results are reported by past researchers [1-10]

Fig 4: Variation in Brake Thermal Efficiency with Respect to Change in Load

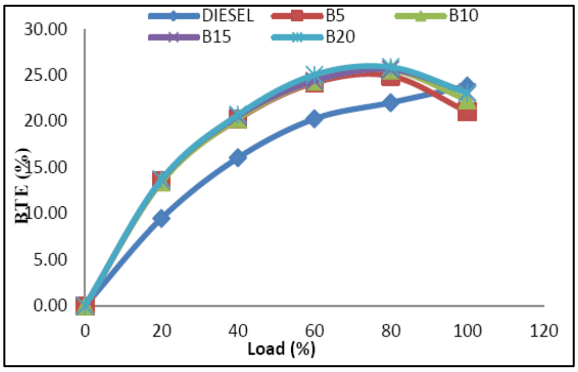
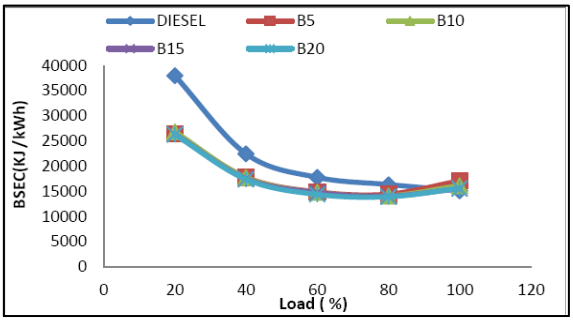


Fig 5: Variation of Brake Specific energy Consumption with Change in Load



5.2.2 Brake specific energy consumption (BSEC)

The variation in BSEC with load for all fuels is presented in Figure 5. In all cases, it decreased sharply with increase in percentage of load for all fuels. The main reason for this could be that the percent increase in fuel required to operate the engine is less than the percent increase in brake power, because relatively less portion of the heat is lost at higher loads. This trend was observed due to lower calorific value, with increase in biodiesel percentage in blends. This trend of BSEC with increasing load in different biodiesel blends were also reported by some researchers [10-25] while testing biodiesel obtained from Mahua oils.

6.0 Conclusions

It is concluded from above study that Mahua oil can be used to produce biodiesel. The optimum parameters for molar ratio of 6:1, Quantity of mahua oil 100gm, Quantity of Methanol 22gm, & 1 gm KOH, Pressure 1 atmosphere, temperature 70^0C, Reaction Time 120 to 150 Minutes with Alkaline Catalyst Method. Further two-step process (Acid catalyst followed by Alkaline Catalyst) may be used to achieve higher yield and lower reaction time. The engine test result revels that brake specific energy consumption of engine is lowerand the brake thermal efficiency is higher with Mahua oil methyl ester-diesel blend than diesel at all loading conditions.

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