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Research and Development of Aviation Bio-Fuel using Jatropha Oil

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Abstract—*This research work paper represents the production and development of Alternative Aviation bio-fuel using Jathropha oil. Other oils can be used for production. But Jathropha seeds were chosen because it is containing 21% to 48% of oil. Also it's not edible therefore; it will not pose any problem to humans and animals in food competition. Before the Transesterification process was carried out, some basic tests such as free fatty acid content, iodine value, and moisture content were carried out. This was done so as to ascertain quality yield of bio- fuel before the reaction the production of the bio-fuel was done with standard materials and under standard conditions which made the production a hitch- free one. The Jathropha oil was heated to 60C, and solution of sodium metho-oxide at (55°C) was added to the oil and stirred for 45 minutes using a magnetic stirrer. The mixture was then left to settle for 24 hours. Glycerine which by-product, was filtered off. The bio-fuel was then thoroughly washed to ensure that it was free from excess methanol and soap. The characterization was comparing with Jet-A1 which preformed was done in Hindustan Petrochemicals' laboratory.*

Keywords: *Jathropa ,Glycerine, Bio-fuel, Trans-esterification, Viscosity*

1. INTRODUCTION

Due to the increased energy demand in the world, there is very high potential for bio-fuels to leverage indigenous sources of inputs. Potential increase in income and opportunities in rural areas. Yet the development of a bio-fuel sector could increase food insecurity for poor consumers. Currently, bio-fuel production is minimal, accounting for only one percentage of production globally. Supporting a future bio-energy sector will likely require policy support (such as stimulus packages), community and local interest, technological advancements, and cost effectives feedstock production. Bio-fuels are potentially important to worldwide because of the significant number of lives they could impact and economic changes they could cause. the terms of bio-fuels refers to several different types of fuels, including bio-ethanol and bio-diesel ,which are both viable options. Bioethanol is the most common form of bio-fuel. It it likely that would use molasses, a by-product of its Jathropha processing industry, to drive ethanol production. On other hand, there are major impediments to larger-scale production and use of bio-ethanol in the world including price competitiveness and production limitation. There is a continuing search for new sources of fuels that are renewable due to the rate of depletion of fossil fuels. The term bio-fuel is used to define fuels that are obtained from plants or animals. Being a renewable source, it is gaining attention all over the world today. Bio-fuel is demand as fuel comprising of mono-alkyl-esters of long fatty acids derived from vegetable oils or Animal fats. These fuels could be either in the form of vegetable oils or animal fats that have been transformed by chemical or natural methods for use in powering various engines. Bio-fuels are obtained from renewable energy sources such as organic materials from living organisms and can also be obtained from biodegradable waste. Hence, the term bio-mass is defined as the source of bio-fuels. These are wastes from plants and animals that are capable of being used as fuels in original form or with little modification. These wastes can also be used in production of fibres and chemicals which are essential in our daily lives. the term bio-fuel is not the same with fuels from fossils, the main difference between bio-fuels and fossil fuels is the content of carbon and the amount of emission they give off when burnt. A large variety of engines manufactured today are made to run on a wide variety of fuels, such as premium motor spirit (petrol), diesel, or gas as their pricipal fuels, with all these types of engines, the diesel engine is the one most suitable to run on bio-fuel. Also, bio-fuels are very similar to petrol and diesel fuel in composition; therefore, there is no need for engine alterations to run on bio-fuels. Bio-fuel engine burns less fuel producing the same amount of work when compared to a petrol engine. Biodiesel is a carbon-neutral source of fuel and is increasingly becoming popular. This is a fuel that is created by chemically processing vegetable oil and altering its properties to make it perform similar to petroleum diesel. Biodiesel is very similar to petro diesel, but they are not identical. However, the difference is really small when we compare the procedure for making biodiesel and petro diesel. Bio-fuel is produced by a process called Trans-esterification; this process involves modifying the chemical properties of a vegetable oil by using methanol. Trans-esterification of vegetable oil is a simple process that yields high conversion with glycerine as the only by-product. In modern times, the need to find and develop alternative energy sources is on the increase; this is largely. The International Air Transport Association (IATA) has approved the use for Alternative bio-fuel energy resources used in aviation purposes in 2008 such as BIO-SPK, FT-SPK, which been implement in many airlines operation.

2. MATERIALS AND APPARATUS

Materials and apparatus used in the production of the bio-fuel are as follows: thermometer, retort stand, pipette, measuring cylinder, separating funnel, magnetic stirrer, oven, water bath, hydrometer, conical flask, digital weighing balance, stop watch, hot plate, distilled water, methanol, and Jathropha oil.

- 2000 ml Jathropha Oil.
- 500 ml Methanol Solution.
- Anhydrous Sodium Hydroxide (NaOH).
- 500 ml graduated cylinder.
- 250 ml graduated cylinder.
- 1L jar (2).
- 1L beaker.
- Scale measuring to at least 0.1gram.
- Hot plate.
- Thermometer (0 – 110 C range).
- Stirring rod.

3. REDUCTION OF THE FATTY ACID

In the test carried out on the Jathropha oil, it was seen that the free fatty acid (FFA) contents of the oil are high (21.6%).Therefore, it became necessary to reduce it.

***Procedure**:* Crude Jathropha oil was poured into a conical flask and heated to a temperature of 60˚ C. A mixture of Concentrated H2SO4 (1% w/w) with methanol (30% v/v) was heated separately at (50˚_C) and then added to the heated oil in the flask. The mixture was stirred for 1 hour and allowed to settle for 2 hours.

3.1 PREPARING OF METHOXIDE SOLUTION

- A small quantity of methanol was poured in a round bottom flask and soxhlet apparatus, and the heater was turned on. this was done to purify the methanol.
- The sodium hydroxide pellet was placed in the weighing balance to get exactly 0.25 g.
- A solution of potassium methoxide was prepared in a 250 mL beaker using 0.25 g (i.e., catalyst concentration of 0.5%) of sodium hydroxide pellet and 63 ml (i.e., mole ratio of oil to methanol of (1: 6) of methanol.
- The solution was properly stirred until sodium hydroxide pellet was completely dissolved.
- The sodium methoxide solution was placed in the oven to bring its temperature to 60℃.

4. TRANSESTERIFICATION PROCESS

One-step alkali based catalyzed Transesterification was carried out for methyl ester production process from CPO, NCO, and CJCO. It is established that Transesterification depends on several basic variables, namely, catalyst type, alcohol type, catalyst -oil ratio, alcohol -oil ratio,

Reaction temperature, reaction time, agitation rate, FFA, and water contents of oils (Ma and Hanna, 1999). In this work, extensive preliminary experimentation with vegetable oils samples showed that it was most efficient to fix reaction temperature at 60 _C, agitation rate 400 rpm, and reaction time for 24 h. Firstly, in the Transesterification process, different catalyst

NaOH -oil ratios (0.5%, 1.0%, 1.5%, 2.0%, 2.5% and 3.0% w/w) and different methanol -oil ratios (10%, 15%, 20%, 25%, 30% and 40% w/w) were used to determine their effect on the methyl ester yields of the oils.All the reactions were carried out in the reaction glass tubes, which were immersed inside a glass water bath placed on the plate of magnetic stirrer of 400 rpm. The temperature and reaction time for all processes were maintained at 65.0 ± 0.5 _C and for 2 h, respectively. After the reaction, the mixture was allowed to settle for 24 h to overnight before separating the glycerol layer and the top layer including methyl ester fraction was removed in separate bottles, weighed and analyzed by GC. Practically, the separated methyl esters must be conducted to remove impurities by washing with hot water until washing water is neutral. However, due to small amount of the oil samples being used in the glass reaction tubes, the refinement stage on this experiment was omitted.

4.1 Procedure:

- 10.5 mL of Jathropha oil was poured into 250 mL conical flask and heated to a temperature of 50℃.
- A small quantity of methanol was poured into a round bottom flask and soxhlet apparatus, and the heater was turned on. this was done to purify the methanol. then sodium hydroxide pellet was placed in the weighing balance to get exactly 0.25 g
- The sodium methoxide solution was kept in the oven to bring its temperature to 60℃.
- The sodium meth-oxide solution was mixed with the warm Jathropha oil and stirred vigorously for 50 minutes using a magnetic stirrer. The mixture was then allowed to settle for 24 hours in a separating funnel.

- The bio-fuel was then poured into a different beaker, while the lower layer (which comprises of glycerol and soap) was collected from the bottom of the separating funnel.
- Washing process will be implementing next forward.

4.2 Chemical Reaction

This reaction is shown in Equation where Rn refers to any fatty acid chain (Meher et al., 2004).Transesterification of triglycerides is a three-step process where alcohol molecules react with one fatty acid chain at a time. The first step is the rate limiting step in which the triglyceride reacts with the alcohol, a diglyceride and ester is formed. The diglyceride then reacts with another alcohol molecule to form a monoglyceride and second ester molecule. Finally, a third molecule of alcohol is reacted with the monoglyceride to form glycerol and a third ester .All three reactions are reversible, so in order for the reaction to proceed forward, there is an excess of alcohol added to the reaction in more than three moles of alcohol for every mole of triglycerides as shown.

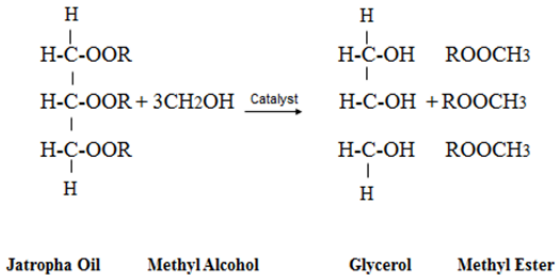

Fig. 4.2

4.3 Post Reaction Processing:

After the Transesterification reaction is complete, there is still a need to purify the fatty Methyl-esters. In the reactor container, there is excess alcohol, free fatty acids, catalyst, and the by-product glycerol.

4.5 Removal of Glycerol

Glycerol can be removed from the ester phase by washing or through a secondary reaction. Washing can be done by either using water or mild acid. It is argued that by Introducing water some of the esters can be lost due to hydrolysis .Due to the possibility of ester lost the excess glycerol in the biodiesel layer can be removed through a reaction with alkaline catalyst instead of water washing. Catalyst is added after the methanol is removed so that the glycerol can be converted to triglycerides. Once the triglycerides have been removed, they can be added to new raw oil and re-enter the process.

After re-entering, they can be converted to usable methyl esters.

4.6 Removal of Methanol

For purification of the ester phase, excess methanol must be removed. Heating of the ester phase will remove the excess methanol. The step to recover methanol should be done prior to any washing procedure, in order to avoid additional processing of methanol to be distilled from water .

4.7 Removal of Free fatty acids

Free fatty acids can be left in the oil. However, they will cause problems with the fuel's efficiency. Free fatty acids can be removed after Transesterification by the addition of acid. As described in acid catalyzed Transesterification, a small amount of acid can be added to react with excess fatty acids .The acid must then be washed out of the solution.

4.8 Removal of Catalyst

Catalyst can be removed from the bio-fuel by-product by washing with water. The Catalyst is more soluble in water than oil so when washed, the catalyst will be removed from the oil and dissolve in the water, which is not soluble with oil (Meher et al., 2004). The mix can then settle and the two layers separated. After all the steps and the process of the Transesterification. The samples had been made for resting time process.

5. PRETREATMENT OF JATROPHA CURCAS OIL

Pre-treatment of J. curcas oil was done by acid catalyzed Transesterification. As stated this is normally done for oils with an acid value above 3mg NaOH/ 1g oil, even though the acid value test showed a value of 2.7mg NaOH/ 1g oil a pre-treatment batch of samples was done to see if it would still increase production of biodiesel.

It was deemed unnecessary to proceed with an acid Catalyzed Transesterification step after comparing the non-pre-treated J. curcas oil to the acid Pre-treated J. curcas oil results after both went through the alkaline catalyzed Transesterification reaction.

The non-pre-treated oil was able to reach a higher bio-fuel yield under a shorter period than the pre-treated oil as shown in Figure 5. In Figure 5-2, the four flasks to the left were not treated with an acid step and the four flasks to the right were treated with an acid step. The figure shows that the four not treated with the acid catalyzed Transesterification are clearer and have less soap formation than the pre-treated samples.

5.1 VARIATION OF REACTION TIME

The one-step alkaline catalyzed Transesterification reaction was followed, running four simultaneous experiments to determine the amount of conversion to ester product. The reactions were removed from the reaction conditions at time intervals of 30, 60, 90, 120 minutes and left to rest at room temperature. Figure 5-3 shows the first four samples in order of lowest to highest reaction time from left to right. In analyzing the samples, it was found that there was not an increase in conversion from the 60 minutes to 120 minutes time interval. Since, heating and agitating are costly processes the lowest reaction time without affecting the yield of bio-fuel was chosen. Graph 5-3 shows the biodiesel yield for samples that used different reaction time. Based on this information the best reaction time was 60 mines because it gave the largest bio-fuel yield for the shortest period of time

5.2 VARIATION OF METHANOL AMOUNTS

Methanol amounts were varied between 5 mL and 20 mL at 5 mL increments. Before removing methanol through processing, 15 mL of methanol added to samples averaged to the highest percent yield of 83.7%. After processing, the same samples had the highest yield of biodiesel product with an average of 55.9%. These data can be seen graphically in the following graph

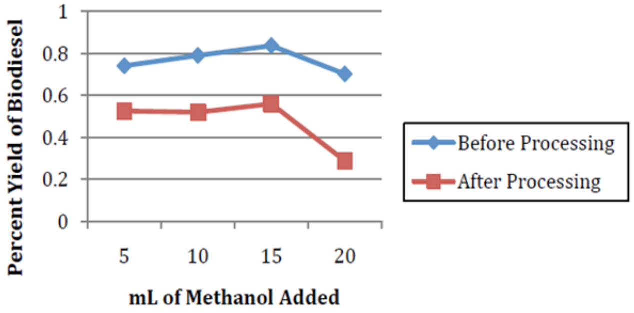

Fig. 5.1

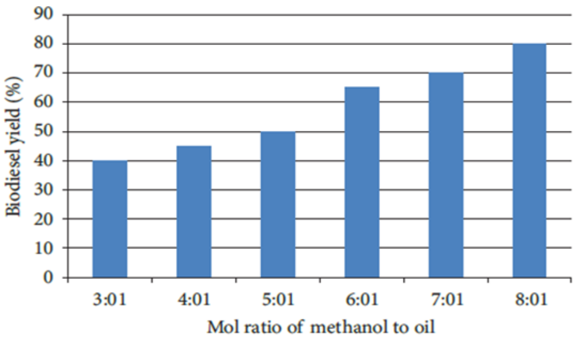

Fig. 5.2: Effect of Mole Ratio Of Methanol to Oil on Bio-fuel Yield

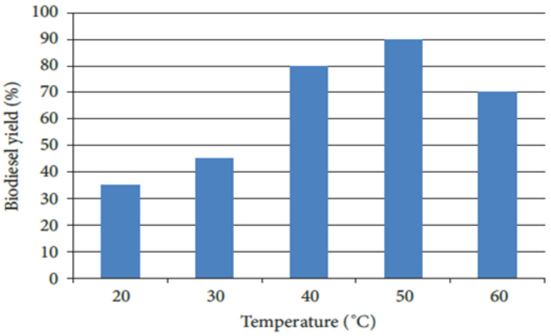

Fig. 5.3: Effect of Temperature of mixture of bio-fuel yield

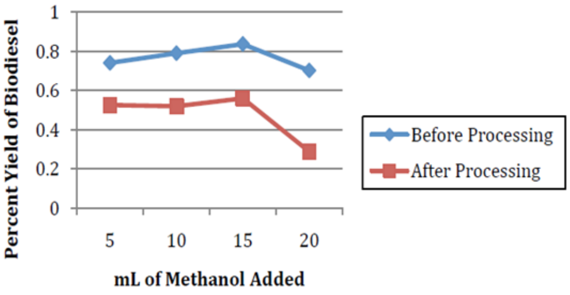

Fig. 5.4

6. CHARACTERIZATION AND RESULT:

6.1 Determination of Viscosity

Procedure: The oil sample was refined through a sintered glass (fire mesh screen) to filter dust and other solid materials. The viscometer was filled with the sample by inverting the tube's thinner arm into the liquid sample and suction force was drawn up to the upper timing mark of the viscometer, after which the instrument was turned to its normal vertical position. the viscometer was placed in a holder and inserted to a constant temperature bath set at 30C; the sample was left for a few minutes until it reached 300℃. the suction force was then applied to the thinner arm to draw the sample slightly above the upper timing mark. the afflux time by timing the flow of the upper timing mark to the lower timing mark was recorded.

6.2 Determination of Moisture Content

Procedure: the oil sample was weighed and the mass taken as ($ww1$) thus was then dried in the oven and then weighed as ($ww2$). the percentage moisture in the oil was then calculated using the formula below:

$$\%\text{ moisture content} = \frac{w_1 - w_2}{w_1} \times 100,$$

....6.1

Where: $ww1$ is the weight of oil sample before drying (grams), and $ww2$ is the weight of oil sample after drying (grams).

6.3 Determination of Free Fatty Acid.

The free fatty acid in the oil was determined by titrating it against Sodium hydroxide (NaOH) using phenolphthalein as indicator.

Procedure. 2 g of oil was dissolved in 50 mL of the neutral solvent in 250 mL conical flask, 3 or 4 drops of phenolphthalein indicator was then added and titrated against 0.1 m NaOH. the content was stirred continuously until a pink colour which persisted for fifteen seconds was obtained.

Determination of specific Gravity.

Density bottle was used to find the density of the oil. A clean dry bottle of 25 mL was weighed ($ww0$) and then filled with the oil; a stopper was inserted and then reweighed to give ($ww1$). the oil was exchanged with water after washing and drying was weighed to give ($ww2$) as

$$\text{Specific gravity} = \frac{w_1 - w_0}{w_2 - w_0}. \qquad \text{.........6.2}$$

6.4 Determination of Iodine Values

Procedure: 0.5 g of the oil was weighed into a 250 cm3 glass stopper bottle. 15 cm3 of chloroform was added to dissolve it, followed by 25 cm3 of wijis iodine solution. the bottle was placed in the dark for 30 minutes, after which 20 cm3 of 15% Sodium iodine (NaI) solution was added; the bottle was closed and shaken vigorously. This solution was titrated against a standard 0.1 m sodium thiosulphate solution. Titration was carried out with constant shaking until yellow colour of iodine almost disappears. 2 cm3 of 1% starch indicator was added and titration continued. When the colour disappeared, bottle was covered with a stopper and shaken vigorously so that all iodine in the organic solvent layer will pass into the water layer. Finally, when the titration was finished, the titter values were recorded. Blank determination was carried out on 5 mL of chloroform and of equal proportion of wijis solution allowing the precipitate to dissolve for same length of time as for the sample analyzed.

6.5 Determination of Saponification Value

Oil of known quantity was refluxed with an excess amount of alcoholic NaOH, after saponification, the remaining NaOH was estimated by titrating against a standard acid.

Procedure: The oil sample was filtered to remove all impurities and last traces of moisture. 5 g of the sample was then weighed into a flask and 5 mL of alcoholic NaOH was added from burette allowing it to drain for the same duration of time. A reflux condenser was connected to the flasks and allowed to boil for one hour. After the flask and condenser get cooled, they were rinsed down the inner part of the condenser with a little distilled water and then the condenser was removed. About 1 mL of indicator was added and titrated against 0.5 m NaCL until the pink colour disappeared.

6.6 Determination of Peroxide Value

The peroxide present was found by titrating against trio-sulphate solution in the presence of NaI using starch as indicator.

Procedure: 1 g of oil was introduced into a clean dry boiling tube. 1 g of powder NaI and 2 mL of solvent mix was added and transferred into boiling water and allowed to boil vigorously for not more than 30 seconds. the content was transferred quickly to a conical flask containing 20 mL of 5% NaI solution. the tube was washed two times with 25 mL of water each time and collected into the conical flask. 0.002 m

Na2S2O3 was titrated with the solution until the yellow colour almost disappeared. Also, 0.5 mL of starch was added and mixed vigorously and was carefully titrated until blue colour just disappeared. A blank was also set at the same time.

TABLE 6.1: Standards specification of Jathropha oil

Property	Value
Colour	4.0
Specific gravity	0.9186
Carbon residue	0.64
Cetane value	51.1
Distillation point	295°C
Kinematic viscosity	50.73 cs
Sulphur %	0.13%
Calorific value	9470 kcal/kg
Pour point	8°C
Acid value	1.0–38.2
Iodine value	90.8–112.5
Saponification value	188–198

TABLE 6.2: Effect of molar ratio of methanol to oil on Bio-fuel Yield

S/no	Molar ratio of methanol to oil (mol)	Biodiesel yield (%)
1	3 : 1	40
2	4 : 1	45
3	5 : 1	50
4	6 : 1	65
5	7 : 1	70
6	8 : 1	80

TABLE 6.3: Effect of temperature of mixture on bio-fuelyield

S/no	Temperature of mixture (°C)	Biodiesel yield (%)
1	20	35
2	30	45
3	40	80
4	50	90
5	60	70

TABLE 6.4: Comparison of Bio-fuel vs. Jet A1

	Jet-A1	Jatropha bio-fuel
Flash Point	38°C	46° C
Freezing Point	-47°C	-57°C
Heat of Combustion	42.8 MJ/Kg	44.3 MJ/Kg
Viscosity (cp) 30c	8mm2/s	3.60mm2/s
Caloric value	10400 kcal / kg	10 170 kcal / kg
Boiling point	149°C	99°C
Density	840 kg/m3	880 kg/m3
Cetane number		50
Carbon residue (%)		0.5

7. DISCUSSIONS OF RESULTS:

The results of this research work will be discoursed under the following groups of solution:

i. Analysis of Jathropha oil samples
ii. Production and development of yield bio-fuel.
iii. Analysis the result and comparison of Jet A1 and bio-fuel.
iv. Suitability of using the bio-fuel in aviation application.

7.1 Analysis of the Jathropha Oil Sample

From Table 1, the various properties of the Jathropha oil used are within range of the standard in Table 1. As observed, the saponification value of the Jathropha oil is 190; this is within the range given in Table 2. this property is very important since if it is too high the formation of soap will be more prevalent instead of the desired bio-fuel. Another property that is very important is the moisture content. From Table 1, the value is 0.20. If the moisture content in the oil sample is too high, soap formation will be more and there will be problems with the separation of the by-product (Glycerin). Free fatty acid level and pH are also very important because more glycerine will be formed if the pH is too high. the two properties are within the range of the standard as seen in the table.

7.2 Production and development of yield bio-fuel

The chemical reaction that yielded the bio-fuel was carried out under standard conditions. Samples were kept at the right temperature, and equipment and materials were kept very clean. The required mol of the catalyst (NaOH) was used so as to prevent emulsification. the mixture was stirred rigorously so that the reactants will mix really well and produce the highest yield of biodiesel possible under the given condition. the bio-fuel thus produced is free from glycerol and soap because warm water was used to wash the bio-fuel. this is necessary so that the properties of the bio-fuel produced should be acceptable when compared with the standard. Emulsification is a major drawback that can occur if the reactants aren’t properly handled, this is a situation whereby soap molecules encase the bio-fuel molecules. this can be corrected (if it happens) by heating the mixture and allowing it to settle. Also, hot solution of sodium chlorine could be used to break the encasing molecules. the heat decreases the density of the oil, while the salt increases density of the water. Two litres of Jathropha oil was used and the yield was two litres of bio-fuel.

7.3 Analysis of the result and comparison of Jet A1 and bio-fuel:

As the result, which the tabulation obtained in the comparison between the jet a1 and the bio-fuel which has been produced accordingly from the Jathropha bio-fuel after subjecting them to certain parameters as shown. We find the thermal efficiency of specific energy has very good yield in the both of type of fuel. Also the caloric values are slightly varying from the Jet a1 but still under the major requirement standards.

7.4 Suitability of using the bio-fuel in aviation application:

Jet fuel is mixture of large number of different hydrocarbons. The range of their sizes is restricted by requirements of the products, for example, freezing point smoking point . jet fuel for sometime classified as kerosene type. Kerosene is include jet a1 ,jet 1 , jet b and jp-4. the drop-in is type of bio-fuel which are completely interchangeable with conventional fuels in purpose to achieve of the required standards. Example of aviation fuel used the drop in concept are Bio-SPK, FT-SPK,.

8. CONCLUSION

In the current investigation, it was confirmed that Jathropha oil may be used as resource to obtain biodiesel. These experimental results show that alkaline-catalyzed Transesterification is a blooming area of research for the production of bio-fuel in large scale. Materials for use in the production of biodiesel are readily available without the need for special equipment or scarce chemicals. Oil from trees can be used in the production of bio-fuel. On a small scale production, the cost of production is low, but if mass production and accuracy is the goal, the cost is going to be high. Glycerin which is the by-product of this chemical reaction can be sold to the pharmaceutical companies since it is used to produce valuables such as creams and toothpaste. Effects of different parameters such as temperature, time, reactant ratio, and catalyst concentration on the bio-fuel yield were also analyzed. The best combination of the parameters was found as 8: 1 molar ratio of methanol to oil, 1.0% NaOH catalyst, 60°_C reaction temperature and 60 minutes of reaction time. This optimum condition yielded 90% of bio-fuel. From the characterization of the bio-fuel, the physical properties of bio-fuel from Jathropha oil with methanol were found to be within the ASTM specified limits. The viscosity of Jathropha oil reduces substantially after Transesterification and is comparable to diesel. Bio-fuel characteristics like density and viscosity are comparable to that of the petrol, diesel.

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