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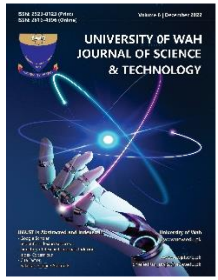


# Optimization of Methanol and Sodium Hydroxide used in the Production of Biodiesel using Jatropha Oil

Ejaz M Shahid[1], Shahab Khushnood[2], and Saad Ejaz[3]
[1] Department of Technology, The University of Lahore, Lahore, Pakistan (ejaz.mehmood@tech.uol.edu.pk).
[2] Department of Machanical Engineering, University of Wah, Wah Cantt, Pakistan (shahab.khushnood@wecuw.edu.pk).
[3] Millat Tractors Lahore (saadejaz50@gmail.com).

Corresponding author email: ejaz.mehmood@tech.uol.edu.pk

**Abstract**

The popularity of biofuel is increasing rapidly due to scarcity of petroleum fuel and its equitableness towards the environment issues. Mostly biodiesel is produced with transesterification, in which organic oils or analogous stuff is reacted with alcohol in the presence of a suitable catalyst.In this study Methanol and Sodium Hydroxide (NaOH), as catalyst, was used to transesterify the Jatropha Oil. Since the economic sustainability is very important, so the study was made to cut down the cost of production of biodiesel. As the cost of Methanol and NaOH is considerable, so the amount of methanol and Sodium Hydroxide was optimized. The amount of methanol varied from 10% to 30% and NaOH varied from 8% to 20%. It was found that 21% methanol and 10.5% NaOH (m/v) revealed the highest yield i.e.96%, when Jatropha oil was used as feedstock. Mathematical model was developed and theoretical results were compared with experimental results. Both models were superimposed and a comprehensive correlation was established.

## Keywords
Transesterifiation, Biodiesel, Sodium Hydroxide, Methanol, Optimization

## 1. Introduction

The energy crises are becoming one of the major challenges to the world, particular for the developing and poor countries. The conventional resources of the energy are mineral oils. Due to tremendous use of mineral oil, flooding of population and mechanization of life, the oil reserves are depleting rapidly. Major portion of the budget is spent on the import of mineral oils. Geo-political situation is another headache of providing and transportation of oil. Environmental deterioration is another challenge to the engineers and scientists. The issue can be handled by replacing mineral oil by biodiesels. Biodiesel can be used in diesel engine without a major modification in the engine. It is a renewable, biodegrade, and environmentally friendly fuel. It was found that it emits lesser amount of carbon monoxide, carbon dioxide, total hydro carbon, toxic compounds, and poly aromatic hydrocarbons [1-3]. As the fuel is free from sulfur so, SOx is not found in the tail pipe of the engine; when it was fueled with biodiesel. Unfortunately, a bit higher amount of NOx was found, which could be controlled by making some design modification and by improving the cooling system of the engine. European countries have decided to raise the share of biofuel from 5.75% to 10% in next coming years [4].Sir Rudolf Diesel was the first scientist, who ran his own diesel engine on peanut oil in an exhibition for several hours, in 1900[5].More than three hundreds feed stocks can be used to produce biodiesel. Many of these can be grown locally [6]. Mohd Nurfirdaus Bin Mohiddin et.al. studied various types of feed stock for the production of biodiesel, techniques and catalysts and concluded that serious efforts must be made in this direction [7].

Mahua Lard, Piqui, Tobacco seed, Brassica carinata, Brassica napus, Rubber plant, Algae, Rice bran, Copra, Fungi, Sesame, Cynara cardunculus, Tarpenes, Barley Latexes, Jatropha Nana, Jatropha Curcas, Jojoba oil, Pongamiaglabra etc.Used cooking oil can also be used for the production of biofuel. In Pakistan, thousands acres barren land is situated, which can be used to grow such plants with little efforts and lesser consumption of water. Jatropha Curcas can be cultivated very easily in the various areas of Pakistan. It can be cultivated in almost every type of area, needs a little quantity of water and care. It is a beautiful flowering plant which can also be grown in gardens, lawn and forests. It can grow well under average rainfall 250 mm. It starts giving fruit from age of three years and maximum at the age of five years. Its life is about 50 years. The plant height is 3 to 8 meters. On an average, the yield of each plant is 5 kg [8]. Jatropha Curcus Oils was used in this study. Vegetable oils can be used to fuel a compression ignition engine directly, in case of emergency [9]. However, the oils are thick, are of higher specific gravity and higher viscosity, due to triglyceride and diglyceride, which can clog filters, fuel injectors, stick on the piston top and rings. Its pour and cloud points are lower and droplet size is bigger, hence difficult to combust. The viscosity of the raw oils is about 10 to 13 times and specific gravity is about 10% higher than those of diesel [10].

So it is not advisable to use it directly. These oils are transesterified using alcohol and suitable catalyst to separate and disintegrate triglyceride and diglyceride and monoglyceride also called free fatty acid (FFA). The properties of FFA are comparable to those of diesel, which can be used to fuel the diesel engines [11]. Alcohol generally (methanol or ethanol) is reacted with vegetable oil in the presence of a suitable catalyst. Triglycerides and diglycerides are disintegrated to monoglycerides. The cost of depends upon cost of organic oil, alcohol and catalyst. In this research, the amount of catalyst and alcohol is optimized to manage the overall cost of biodiesel.As long as alcohol is concerned almost 50% extra ethanol is consumed as compared to methanol. Moreover the methanol is widely used in others areas and its price is higher as compared to methanol. Hence only methanol was used in this study.Various types of catalysts can be used for transesterifiation which include acid, base and enzyme catalysts. In this study base catalyst was experimented. Furthermore, in base catalysts, both Potassium and Sodium hydroxides are used but the Sodium Hydroxide (NaOH) is preferred due to its lower cost and less saponification.

## 2. Experimental Setup

### 2.1. Transesterification

Three molecules of glyceride are linked with one molecule of glycerol, which is separated when it is reacted with alcohol. It results in three molecules of alcohol ester and one molecule of glycerol, as shown below the process is termed as transesterifiation.

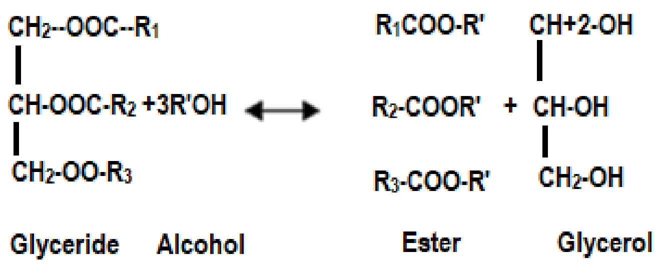


***Fig. 1. Transesterification Reaction***

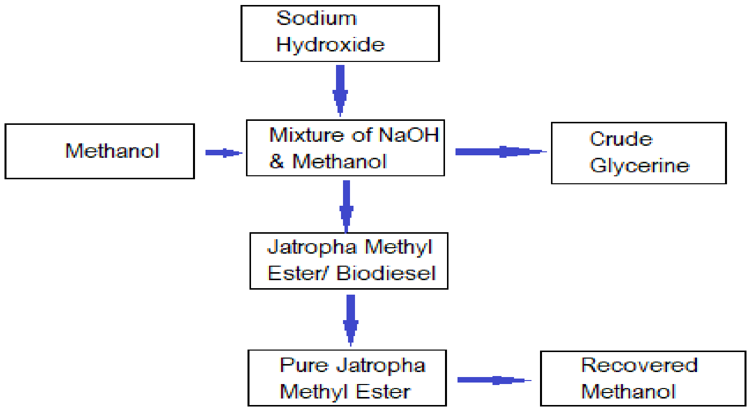


***Fig. 2. Line diagram of Experimental Setup***

One liter, pure Jatropha Curcas oil was heated to 65ºC. NaOH was added in the methanol. The mixture was stirred vigorously, so as to achieve a homogenous mixture. Then the oil was poured into vessel and the solution of methanol and NaOH was also poured into the vessel. The mixture was agitated for 15 minutes and then poured into a separating funnel. It was allowed to complete the reaction and to settle for two hours.Then the fluid was found in three distinct layers. A thick layer of dark brown color was settled in the bottom (glycerol), pale yellow color layer (methyl ester) at the top. A spongy, unreacted, contaminated mixture was found in the middle. Methyl ester, glycerol and unreacted mixture were separated and measured.Methyl ester was purified, dried and measured carefully. The process was repeated again and again by varying the amount of methanol and NaOH.

## 3. Optimization

The methanol and sodium hydroxide was optimized experimentally and then both parameters were modeled. Finally both were superimposed.

### 3.1. Optimization of Methanol

In the first stage the amount of alcohol for the production of biodiesel, using Jatropha Oil as feedstock was optimized. The experiments were carried out at 65°C, by using 30% methanol, and 1% NaOH. The mixture was poured into the reaction vessel and allowed to react for two hours. The methyl ester (biodiesel) was separated and washed with warm water repeatedly till the crystal clear water was found. It was found that the yield was 91%. Some amount of unreacted methanol was also found which was separated by distillation method.The experiments were repeated by varying methanol from 15% to 30%. The conversion efficiency was increased to 94% and started decreasing to 65%, as shown Fig. 3. Chemically, 12 to 14% of methanol, depending upon quality and species of Jatropha oil, is required for transesterification process. Since the reaction is reversible so higher amount of alcohol should be applied for better conversion efficiency. However, at the end, the excess/ unreacted amount of methanol can be recovered.

The amount of alcohol was varied from 10% to 30% while the amount of catalyst, reaction time and reaction temperature were kept constant. The yield was found 73 to 94%. The difference of yield was very little from 18 to 22%, though, the highest yield was found when 21% methanol was applied. The yield started decreasing when the higher amount of methanol was applied, as shown in Fig. 3 which was perhaps due to reversibility of the reaction.

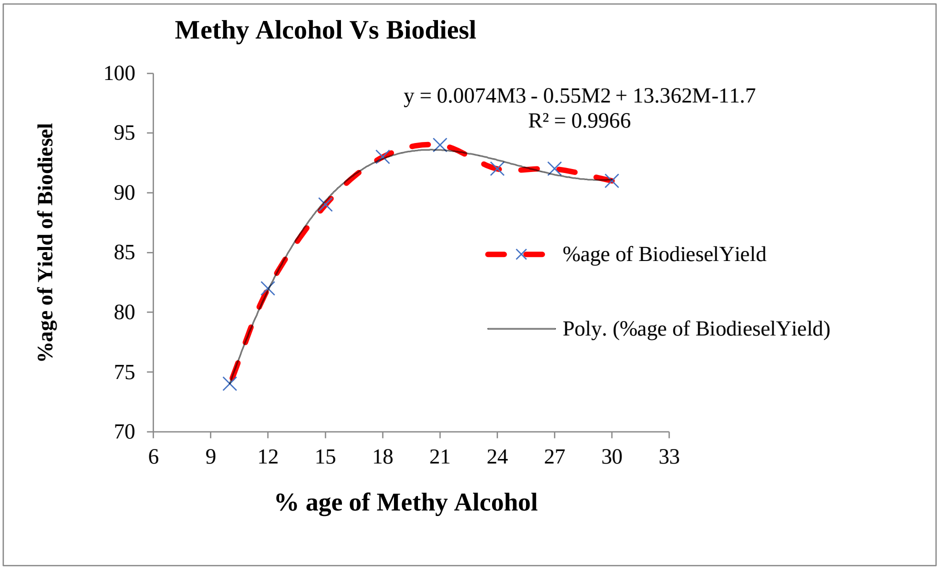


*Fig. 3. Yield of biodiesel with variation in amount of Methanol*

It was it was found that maximum yield of biodiesel can be obtained by applying 21% Methanol to transesterify Jatropha Oil. The results are very close to those of others scientists and researchers. Refaat et al. transesterified concluded that 20% methanol returns the best yield when it was applied on used cooking oil [12]. Sharma and Sing were of view that 20% alcohol is suitable to transesterify Jatropha Oil [13].

**Table 1:** Yield of biodiesel with variation of amount of Methanol

| %age of Methanol | %age of Yield of Biodiesel |
|---|---|
| 10 | 74 |
| 12 | 82 |
| 15 | 89 |
| 18 | 93 |
| 21 | 94 |
| 27 | 92 |
| 30 | 91 |

The data was modeled as follows:

$$Y = 0074M^3 - 0.5523M^2 + 13.362M - 11.714$$

The highest yield 94% was also obtained by applying 21% methanol which also testifies the mathematical results that 93.68% yield would be obtained by applying 21% methanol.

### 3.2. Optimization of Catalysts

Different types of catalysts can be used for the development of biodiesel which includes enzymes, organic, homogenous and heterogeneous acid and base catalysts. But homogenous catalysts are more popular as compared to others because of shorter reaction times and better conversion efficiency [14]. Among the homogenous base catalysts, Potassium hydroxide (KOH) and Sodium hydroxide are oftenly employed[15].In this study NaOH was used because it is cheaper and less quantity is used as compared to KOH. The first experiment was conducted by using 20 gram NaOH/ liter of Jatropha oil, while 21% methanol was applied and temperature was maintained at 65°C. After the completion of the reaction, the biodiesel was separated and washed with warm water. Huge amount of fog was found, which showed that excess amount of NaOH was available in the biodiesel. After a series of washing pure biodiesel was found. Almost 96% of oil was converted into biodiesel. The experiments were repeated by reducing NaOH by two gram each time. The conversion efficiency remained between 95 and 96% till 12 gram per liter. The conversion efficiency was declined when 10 and 8 gram NaOH was applied. It went on decreasing with decrease of amount of NaOH. Hence it was established that the optimum point lies between 12 and 10 gram of NaOH. The experiments were repeated by 11.5, using 11.0, 10.5 and 10.25 gram of catalyst and the highest yield (96%) was obtained by applying 10.5 gram (1.05%). The data was modeled as shown in Fig 4.

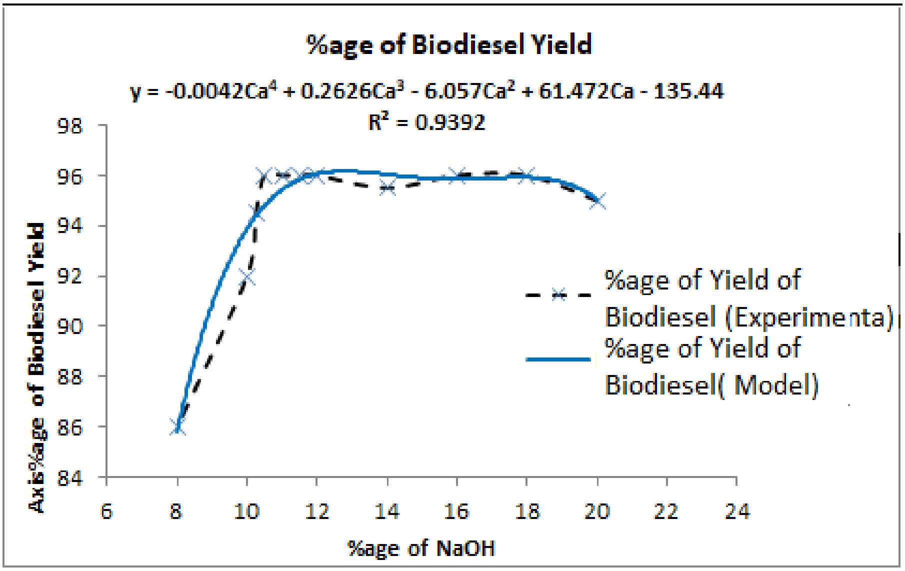


***Fig. 4. Yield of biodiesel with variation in amount of NaOH***

**Table 2**: Yield of biodiesel with variation amount of NaOH

| %age o f NaOH | %age of Yield of Biodiesel |
|---|---|
| 2 | 95 |
| 1.8 | 96 |
| 1.6 | 96 |
| 1.4 | 95.5 |
| 1.2 | 96 |
| 1.15 | 96 |
| 1.1 | 96 |
| 1.05 | 96 |
| 1.025 | 94.5 |
| 1 | 92 |
| 0.8 | 86 |

$$Y = -0.0042Ca^4 + 0.26Ca^3 - 6.057Ca^2 + 61.47Ca - 135.44$$

As the data is scattered so a complex model was built. Leung and Guo concluded that 90.4 % yield was obtained when used cooking oil was transesterified using 1% NaOH and methanol/oil molar ratio was 7: 1 [15]. While Sharma and Singh found 98% conversion efficiency when 1% NaOH was used to convert Jatropha curcus oil [13]. Lubes and Zakaria developed biodiesel using waste edible oil and remarked that 95% biodiesel can be obtained when 1% NaOH is used with methanol/oil molar ratio of 6. [16].

### 3.3. Superimposing Models

Both models were superimposed and comprehensive model was developed. In this model both parameters (methanol and sodium hydroxide) were considered as variable and finally a comprehensive model was developed as given below:

$$Y =(-0.31Ca^4M^3+23.37Ca^4M^2-565.35Ca^4M+ 495.62Ca^4 + 1.94Ca^3M^3$$

$$145.03Ca^3M^2+3508.86Ca^3M- 3076.1Ca^3- 4.48Ca^2M^3+334.53Ca^2M^2-8093.36Ca^2M + 7095.17Ca^2$$

$$+4.55Ca M^3-339.51Ca M^2+ 8213.89Ca M-7200.83Ca -0.00206M^3+74.78915M^2$$

$$1809.4M+1586.24)^{0.5}$$

The values were substituted in the correlation and theoretical %age of yields of biodiesel was found similar to those of experimental values in Table 3.

**Table 3:** Yield of biodiesel with variation of amount of Methanol and NaOH

| Catalyst NaOH % | Alcohol Methanol | % of Yield of Biodiesel | Catalyst NaOH % | Alcohol Methanol | % of Yield of Biodiesel |
|---|---|---|---|---|---|
| 0.60 | 10 | 83.91 | 1.00 | 18 | 93.44 |
| 1.60 | 10 | 84.26 | 0.80 | 18 | 89.34 |
| 1.20 | 10 | 84.35 | 2.00 | 21 | 94.45 |
| 1.00 | 10 | 83.39 | 1.60 | 21 | 94.85 |
| .80 | 12 | 83.82 | 1.20 | 21 | 94.95 |
| 2.00 | 12 | 88.22 | 1.00 | 21 | 93.86 |
| 1.60 | 12 | 88.59 | 0.80 | 21 | 89.74 |
| 1.20 | 12 | 88.69 | 2.00 | 27 | 93.55 |
| 1.00 | 12 | 87.67 | 1.60 | 27 | 93.95 |
| 0.80 | 15 | 87.60 | 1.20 | 27 | 94.05 |
| 2.00 | 15 | 92.19 | 1.00 | 27 | 92.97 |
| 1.60 | 15 | 92.58 | 0.80 | 27 | 88.89 |
| 1.20 | 15 | 92.68 | 2.00 | 30 | 93.44 |
| 1.00 | 15 | 91.62 | 1.60 | 30 | 93.84 |
| 0.80 | 15 | 87.60 | 1.20 | 30 | 93.94 |
| 2.00 | 18 | 94.02 | 1.00 | 30 | 92.87 |
| 1.60 | 18 | 94.42 | 0.80 | 30 | 88.79 |
| 1.20 | 18 | 94.52 | | | |

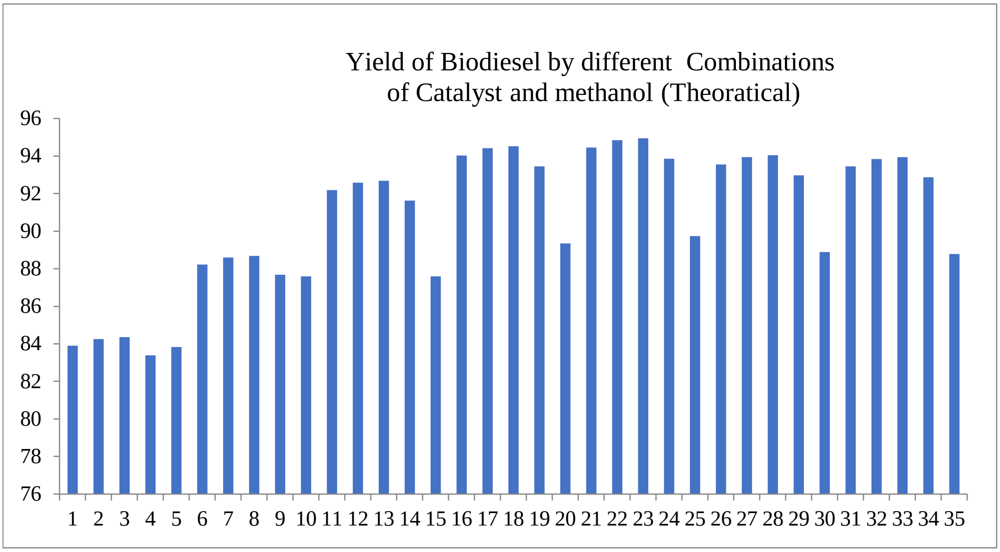


***Fig. 5 Yield of biodiesel with variation in the amount of NaOH and alcohol determined mathematically.***

The model indicated that 94.8% yield will be found when 21% methanol and 1.05% sodium hydroxide is used to transesterify the Jatropha oil. It also validates the earlier developed models and experimental results.

## 4. Properties of Biodiesel

Finally the properties of biodiesel were tested in accordance with ASTM 6751. The properties were found and compared with those of mineral diesel, as shown in the Table 4.

**Table 4:** Properties of Diesel and JME.

| Property | Unit | Diesel | JME | ASTM D6751 |
|---|---|---|---|---|
| Density at 20°C | kg/m3 | 850 | 880 | 870–890 |
| Kinematic Viscosity at 40°C | mm2/s | 3.6 | 3.82 | 1.9 to 6.0 |
| Flash Point | °C | 68 | 185 | > 120 |
| Pour Point | °C | –6 | –8 | –15 to 10 |
| Calorific Value | MJ/kg | 42 | 38.5 | -- |

## 5. Conclusion

1. Biodiesel can be an alternative fuel which can be used to run the compression ignition engines.
2. It is an environmental friendly fuel. The amount of CO, CO2, THC and other pollutant emissions are reduced when the engine is fueled with biodiesel.
3. It is cheap and economical fuel.
4. Jatropha oil can be very good stuff to produce biodiesel.
5. It can be grown and developed locally.
6. 96% conversion efficiency can be achieved when 21% methyl alcohol and 1.05% sodium hydroxide is used to transesterify the Jatropha oil.
7. It is safe to store and transport however its shelf life is just six months.

## Acknowledgement

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