A Study on Optimization of Biodiesel Production from Pongamia Oil

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Abstract: ***Due to the high rate of fossil fuel depletion and environmental concerns, the use of biodiesel as an alternative for diesel engines has gained its significance. Biodiesel can be produced by various methodsand a lot of researches are going on over the effects of performance, combustion and emission characteristics of engine using the biodiesel. This paper presents the transesterification of Pongamia oil into Pongamia methyl ester and optimization of the processes. The yield of biodiesel depends on the reaction time, reaction temperature and concentration of catalyst and molar ratio of alcohol. Optimization of each parameter is done keeping others a constant. The study shows that maximum yield was obtained when 0.2wt% of catalyst is used with 150% excess alcohol at 60o C for 2 hours. The biodiesel obtained is of high quality and can be used directly in the diesel engine without any modification.***

Keywords: Biodiesel, Pongamia Methyl Ester (PME), Transesterification, Optimization.

1. Introduction

Even though the idea of using biodiesel was introduced primarily by Rudolf Diesel in 1910, it was in late 70's that it became popular and strong due to first fuel crisis. The raw oil or straight vegetable oil can be used directly in the engine but it will pose great problems in long term usage. So these straight vegetable oils are converted into methyl ester by the process of transesterification [11]. The problems of using straight vegetable oil includes knocking, carbon deposition, injector chocking and the reasons for this include low atomization, high viscosity and low volatility[4]. So reducing the viscosity is a very important process which increases the atomisation of fuel and thereby increasing maximum mixing which in turn increases the rate of combustion [5].

Pongamia oil is a nonedible oil which can be grown in waste and non-fertile lands. Tropic climate is best suited for these trees and requires very little water which makes it best competitor in India among other nonedible. Pongamia and Jatropha are considered as best alternatives for diesel because they are non-edible and requires very little caring. Pongamia (Honge) is a medium sized tree which grows in Indian sub-continent and has successfully introduced and cultivated in other tropical areas especially in those countries which are near to the equatorial regions[9]. A single tree is expected to yield 9-90 kg of seed with a yield potential of 900-9000kg seed/ha [assuming 100 trees/ha] [6]. The plant is fast growing, highly tolerant to salinity and drought resistant [3].The oil content in the seed of Pongamia ranges from 35 to 45 wt% and the oil consists of oleic acid and unsaponifiable matters [1].

Different methods are available for producing methyl esters of oil such as blending of alcohol and oil, micro emulsion, transesterification, pyrolysis etc. out of these transesterification is the most commonly used and effective[10]. Methyl esters are clean burning bio fuels with low amount of sulphur and lead content which makes them more environmental friendly. These are non-corrosive and produced at low pressure and temperature conditions and gives glycerine as bi product of the chemical process [3].

Biodiesel production procedure has a crucial role in obtaining good quality product. Since this process is in its rising stage it is very essential for optimizing the entire reaction process. Obtaining maximum quantity and quality product is important. In this present paper work effort is made to optimize the transesterification process for Pongamia oil using methanol and NaOH as alkali catalyst.

2. Materials and Method

Transesterification reaction is a reversible reaction, which when carried out in the presence of acid, alkali, enzyme catalyst, the triglyceride chains gets converted into alkyl fatty acid esters and glycerol. The fatty acid ester is the biodiesel which can be used directly in the engine. The properties of biodiesel depend on the characteristics of oil and the method of production [13]. In raw oil there are two kinds of fatty acids viz. saturated and unsaturated. Oils with more saturated fatty acid esters show poor cold flow properties and those with unsaturated esters show more oxidation instability [2]. For finding the acid content and nature of oil gas chromatography technique is used which gives the mass spectrum of each acid contained in the raw oil.

Depending upon the fatty acid content and amount of moisture in the raw oil the reaction procedure also changes. Figure 1 shows the flow chart indicating the entire transesterification process. If the free fatty acid content is more than 1% then acid catalysed reaction should be carried out, commonly used acid catalysts are sulphuric or hydrochloric acid. This requires more time for completing the reaction even upto 48 hours. On the other hand if the free fatty acid content is less than 1% the alkali based reaction can be carried out which requires 2 to 3 hours.

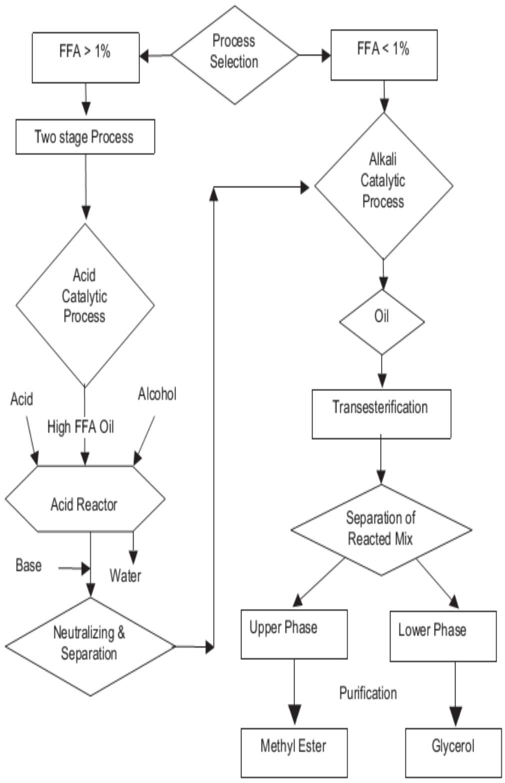

Figure 1: Flow chart of transesterification reaction

The entire transesterification reaction based on alkali catalyst requires a reaction time of 2 hours. The basic step includes the mixing of raw oil with alcohol and add catalyst to it alternatively alcohol and catalyst can be mixed and added to oil. Alcohol should be in excess in the mixture for getting maximum yield of ester from the reaction. This mixture is heated and stirred at constant temperature for one hour. The temperature range should be maintained between 60o C and 70o C. Once the reaction time is over, the mixture is allowed to settle under gravity. In the separation flask there will be two layers, top layer is the biodiesel which is separated from bottom layer of glycerol. Normally the yield of alkyl esters ranges from 65% to 95% depending upon the various factors such as reaction time, temperature, catalyst and molar ratio of alcohol and oil.

For achieving maximum yield of alkyl ester (biodiesel), transesterification process was optimized by varying process parameters. Various factors considered for optimization were reaction temperature, percentage of methanol, amount of NaOH catalyst, reaction time.

3. Results and discussion

Tests were conducted to determine the physical and chemical properties of raw Pongamia oil and the Pongamia Methyl Esters. First the mass spectrum of the Pongamia oil was studied in order to select the transesterification process. The results of gas chromatographic test are shown in the chart below which indicates the fatty acid content and the retention time.

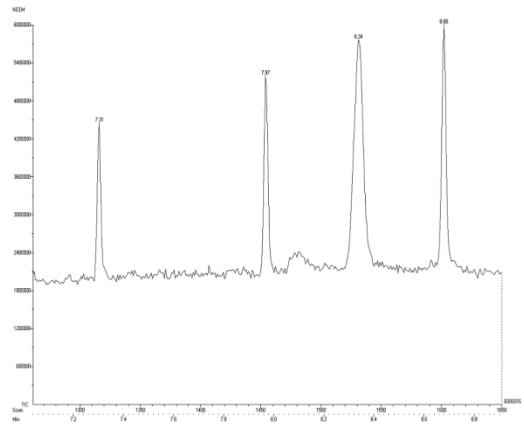

Figure 2: Mass spectrum of Pongamia oil

From the results obtained the free fatty acid content in the Pongamia oil was less than 1% of the feedstock. So the transesterification process used was alkali based transesterification reaction.

Property	*Value*
Density (gm/cc)	0.927
Kinematic Viscosity (mm2/s)	27.8
Calorific Value (Kcal/kg)	8740
Cetane Number	42
Flash Point (oC)	225
Fire Point (oC)	230
Cloud Point (oC)	3.5
Pour Point (oC)	-3
Boiling Point (oC)	316
Acid Value (mg/KOH)	5.40

Table 1: Properties of Pongamia oil

Property	*PME*	*Diesel*
Density (gm/cc)	0.864	0.824
Calorific value (Kcal/kg)	3800	4285
Cetane Number	43	48
Kinematic Viscosity (cSt)	4.42	3.27
Acid Value (mg/KOH)	0.44	0.38

Table 2: Properties of Pongamia methyl ester and diesel

3.1 Effect of reaction temperature

The yield of alkyl esters (biodiesel) is found to be varying with variation in reaction temperature. It can be observed from Figure 3 that when the temperature was varied from 50o C to 70o C the yield of product increased with increase in temperature up to 65o C and then reduced. So it is concluded that the optimum temperature is 65o C for Pongamia and methanol in the presence of NaOH catalyst.

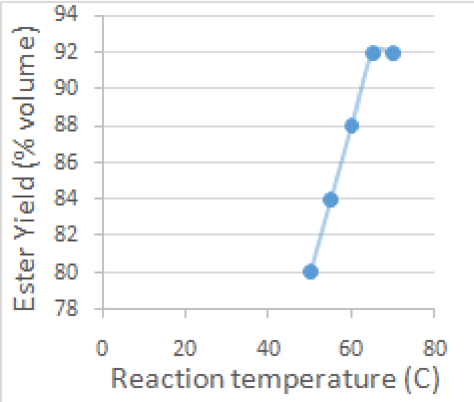

Figure 3: Effect of temperature on yield of ester

3.2 Effect of varying the amount of methanol

From Figure 4it is found that the yield of product is considerably influenced by the variation in the amount of methanol used in the reaction. Theoretically 3 moles of methanol is required for 1 mole of raw oil to produce 3 moles of biodiesel and 1 mole of glycerine. So, for obtaining more yields excess alcohol must be used. Figure 4 shows a steady increase in yield of ester up to 150 wt% excess alcohols and then it remains constant even when amount of alcohol is increased.

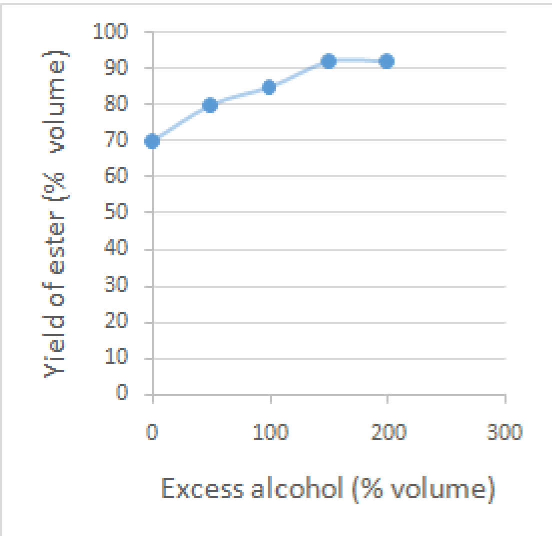

Figure 4: Effect of excess alcohol on yield of ester

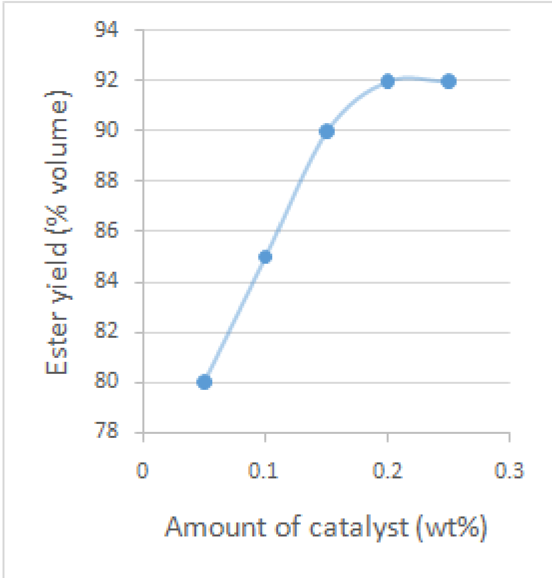

Figure 5: Effect of catalyst concentration on ester yield

3.3 Effect of amount of catalyst

Catalyst amount also plays an important role in maximising the product yield. Figure 5 indicates the change in yield of alkyl ester with change in amount of catalyst. It is found that the amount of product increases as the catalyst amount increases, but it also shows that after 0.2 wt% of catalyst the yield remains more or less constant. So it is better to use 0.2 wt% of catalyst for obtaining maximum amount of product.

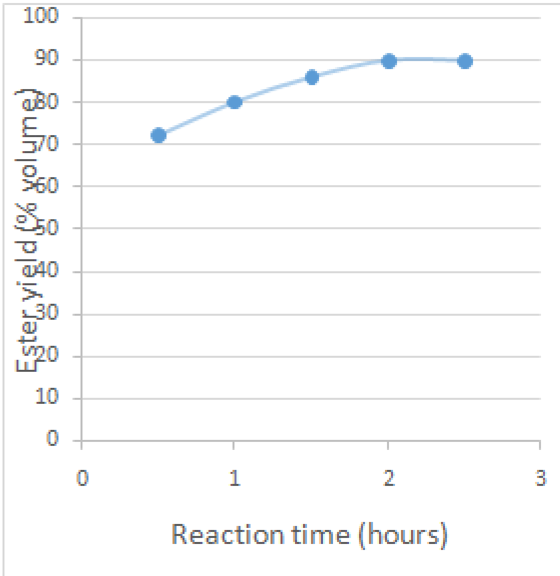

Figure 6: Effect of reaction time on ester yield

3.4 Effect of reaction time

By varying the length of reaction time the amount of product obtained also varies. The reaction time is varied form 0.5 hours to 3 hours and yield is observed and result obtained is shown in Figure 6. The amount of alkyl ester increased with reaction time, but after 2 hours the yield remained constant and it is found that 2 hours is the optimum time period for the transesterification to occur.

4. Conclusions

An intensive and detailed study was conducted on using Pongamia as an alternative for fuelling diesel engines and ways to optimize the transesterification reaction of Pongamia using methanol and NaOH catalyst. From the study it is concluded that Pongamia methyl ester can be a potential substitute for conventional diesel fuel. It can be observed that optimum conditions for carrying out the transesterification reaction is by using 150 wt% excess methanol and 0.2 wt% of NaOH catalyst and maintaining the reaction temperature at 65oC for about 2 hours. So Pongamia methyl ester (PME) can be used directly in diesel fuelled engines without any modifications since its properties are close to the conventional diesel fuel.

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Author Profile

Viswanath K Kaimal received his B.Tech degree in Mechanical Engineering from Jyothi Engineering College in 2007. He is currently pursuing his Post Graduation (M.Tech) in Thermal Engineering from Hindustan Institute of Technology and Science. Presently he is working on his M.Tech thesis which is to evaluate the possibility of using Pongamia Methyl Ester as an alternate for diesel fuel in conventional CI engine.