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Transesterification of *Pongamia pinnata* Oil Using Base Catalysts: A Laboratory Scale Study

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Abstract:

Pongamia pinnata is a deciduous, salt tolerant, drought resistant nitrogen fixing leguminous tree and their seeds are well known for extraction of non-edible oil. In the present study, the crude oil extracted from Pongamia pinnata seed was used to synthesize biodiesel (fatty acid methyl esters) by tranesterification with methanol in the presence of two different base catalysts viz. NaOH and KOH at a predetermined optimum temperature of 60˚C, stirring speed of 300 rpm for 45 minutes. A percentage conversion of 68% and 73% respectively was achieved by NaOH and KOH catalyzed transesterification reaction. Further, fuel properties of the transesterified oil (biodiesel) obtained using the two catalysts were compared with crude Pongamia oil and a biodiesel blend (B20). Fuel properties taken into consideration were density, viscosity and flash point.

Keywords: *Pongamia pinnata*; Non-edible oil; Base catalyst; Transetserification; Biodiesel; B20

1. Introduction:

Biodiesel, an alternative diesel fuel is derived from a chemical reaction called transesterifcation of plant-derived oil (Barnwal, 2005). It is the chemical conversion of oil to its corresponding fatty ester in the presence of a catalyst (Bala, 2005). The reaction converts esters from long chain fatty acids into mono alkyl esters. Chemically, biodiesel is a fatty acid methyl ester. Transesterification process helps reduce the viscosity of the oil. The process proceeds well in the presence of homogenous catalysts such as sodium hydroxide (NaOH), potassium hydroxide (KOH), sulphuric acid (Demirbas, 2008). Bases catalyze the reaction by removing a proton from the alcohol, which acids donate protons to the carbonyl group making the reactions more reactive (Schuchardt et al., 1998). Besides acids and bases, transesterification can also be catalyzed in the presence of enzymes (Hama et al., 2004 and Shimada et al., 2002).

Biodiesel is gaining increasing acceptance in the market as an environmental friendly alternative diesel fuel(Jidon Janaun et al. 2010). It is non-toxic, biodegradable, and free of sulphur or any carcinogenic compounds (Demirbas, 2002). The demand and cost of edible oils prevents its use in the production of biodiesel. So, a large variety of plants that produce non-edible oils are considered for biodiesel production. In India, there are several non-edible oil seed species such as*Jatropha curcas* (Jatropha),*Pongamia pinnata* (Karanja), *Azadirachta indica* (Neem), *Madhuca iondica* (Mahua) etc., which could be utilized as a source for production of oil (Meher et al., 2006) and can be grown in large scale on non-cropped marginal lands and waste lands (Gerhard,2005). Fatty acid profiles of seed oils of 75 plant species having 30% or more fixed oil in their seed/kernel were examined (Mohibee, 2005), in which*A. indica, Calophyllum inophyllum, J.curcas* and *P. pinnata* were found to be most suitable for use as biodiesel and they meet the major specification of biodiesel standards of USA, Germany and European Standard Organization.

Pongamia pinnata (Karanja) is deciduous, salt tolerant, drought resistant nitrogen fixing leguminous tree. It is an oil seed-bearing tree, native to humid and subtropical environments and can grow in a wide variety of soil types. The presence of toxic flavonoids like karanjin, pongapin and pongaglabrin in the oil, makes it non-edible with only 6% being utilized out of 200 million tons produced per year. The synthesis of biodiesel from edible oils like palm oil and groundnut oil and from crude non-edible oils like *Pongamia pinnata* and *Jatropha curcas* were investigated earlier (Vivek and Giridhar, 2007).

The oil content of the *Pongamia pinnata*seed kernel is 30–40%. This dark brown oil has a repulsive odor and shows fungicidal properties (Sanjib, 2005). The oil contains primarily eight fatty acids viz. palmitic, stearic, oleic, linoleic, lignoceric, eicosenoic, arachidic and behenic (Lakshmikanthan, 1978). Of these, the four which are commonly found in most oils, including Pongamia, are the saturated acids, palmitic (Hexadecanoic acid) and stearic (Octadecanoic acid) and the unsaturated acids, oleic (Octadec-9-enoic acid) and linoleic (9, 12octadecadienoic acid).*Pongamia* oil contains oleic acid (44.5–71.3%) as the major fatty acid followed by linoleic (10.8–18.3%), palmitic (3.7–7.9%) and stearic (2.4–8.9%) acids. In addition to these four fatty acids, Pongamia oil also contains eicosenoic acid (9-eicosenoic acid) in reasonable amounts (9.5–12.4%).The fatty acid composition percentage of *Pongamia* oil determined by gas chromatography and its physicochemical properties determined as per BIS method are reported in Table 1 and 2 respectively (Meher et al., 2004).

The primary objective of this study was to determine the effect of different base catalysts viz. NaOH and KOH on the transesterification of *Pongamia* oil for the production of biodiesel. The second objective is to test certain important fuel properties of the synthesized biodiesel and compare it against crude *Pongamia* oil, B20 and biodiesel standards.

2. Materials and Methods:

2.1. Materials

Crude Pongamia oil was collected locally and used. Chemicals including Methanol, sodium hydroxide (NaOH) and potassium hydroxide (KOH) were obtained and used without any further purification. Pongamia oil was preheated prior to its use in transesterification process to remove the moisture content.

2.2. Experimental Procedure

*TRANSESTERIFICATION OF PONGAMIA OIL USING BASE CATALYST (NaOH AND KOH):*Oil can be transesterified by heating them with a large excess of anhydrous methanol and a catalyst.In this study, the anhydrous crude oil was taken in two separate beakers and heated upto 60 ˚C (Figure 1).Methanol with measured quantities of catalysts dissolved in it by vigorous stirring was respectively added to the beakers containing oil. The reaction mixture was stirred at 300 rpm for 45 minutes at 60 ˚C (Figure 2).

The transesterified oil was then cooled and subsequently allowed to settle overnight in a separating funnel (Figure 3). The transesterification process results in two liquid phases: ester and crude glycerin. Crude glycerin, the heavier part is separated after complete settling in a separating funnel. The remaining ester (biodiesel) is washed several times with water until the ester layer becomes clear (Figure 4 and 5). The resultant biodiesel is collected and stored for further studies.

3. Results and Discussions

3.1 Effect of NaOH:

Transestrification of *Pongamia* oil with NaOH as catalyst yielded 68% of biodiesel. *Pongamia* oil contains higher acid value (also signifies high free fatty acid content) therefore, for any alkali-catalyzed transesterification, the alkali (NaOH/KOH) catalyst that is used will react with free fatty acid (FFA) to form soap. The saponification reaction of NaOH and FFA formed soap and water. The soaps increase themethyl ester solubility in glycerol and produce emulsification ofthe ester and glycerol that makes difficulties in the separation ofthe esters (Kafuku and Mbarawa, 2010). Therefore ester losses increase and consequently the product and biodiesel yield decreases (Phan and Phan, 2008). In this study, soap formation was considerable, and hence the biodiesel yield was low.

3.2 Effect of KOH:

Transestrification of *Pongamia* oil with KOH as catalyst yielded 73% of biodiesel. It was found that biodiesel yield percent obtained using KOH was more than that of biodiesel yield percent obtained by NaOH.It was observed that the soap formation during this process was less than that of NaOH catalyzed transesterification reaction, and has contributed to the little higher yield of biodiesel (Mehdi, 2011).

3.3 Fuel Property

Certain important fuel property such as density, kinematic viscosity and flash point synthesized biodiesel (using NaOH and KOH), crude *Pongamia* oil and B20 were studied and compared with biodiesel standards (Figure 8). Viscosity and flash point are the important parameter that has to be considered. Our present study also reports the effect of temperature on viscosity of oil, biodiesel and B20 (Figure 6 and 7).And the values are reported in Table 3.

3.3.1 Viscosity

Viscosity is the measure of resistance to flow of a liquid due to internal friction of one part of a fluid moving over another affects the atomization of a fuel upon injection into the combustion chamber and thereby, ultimately leads to the formation of engine deposits. The higher the viscosity, the greater is thetendency of the fuel to cause such problems (Ma, 1999). The values of kinematic viscosity are reported in the Table 4.It was found that the viscosity of the synthesized biodiesel was higher than the specifications of biodiesel standards.

3.3.2 Flash Point and Fire Point

The flash point of a volatile liquid is the lowest temperature at which it can vaporize to form an ignitable mixture in air. The fire point is defined as the temperature at which the vapor continues to burn after being ignited. The flash point is often used as a descriptive characteristic of liquid fuel, and it is also used to help characterize the fire hazards of liquids. Therefore it has been considered as an important fuel property. The values of flash point of oil, synthesized biodiesel and B20 are reported in Table 3. The higher value of flash point as observed in this study has a higher safety than the petroleum diesel for transport purposes (Mehdi, 2011).

Fig. 1 Preheating of pongamia oil

Fig. 2 Trasesterification

Fig. 3 Settling **Fig. 4** Separation **Fig. 5** Water Washing

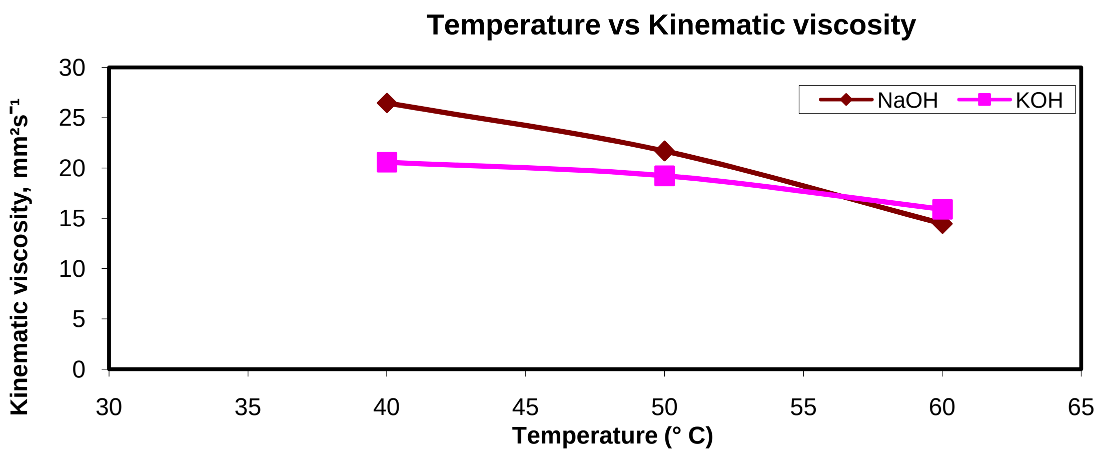

Figure 6 Effect of Temperature on Viscosity of Biodiesel obtained by using catalyst NaOH and KOH. (As the temperature increases the viscosity decreases)

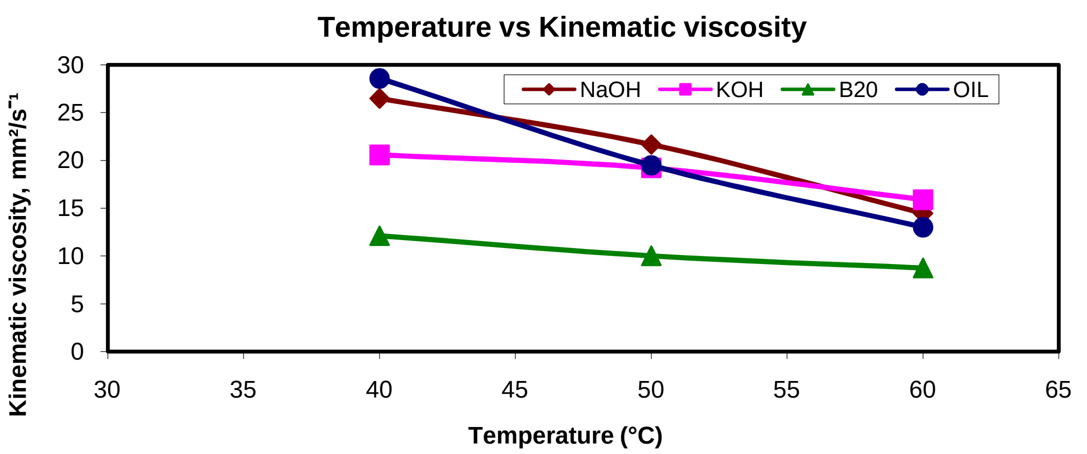

Fig.7 Effect of Temperature on Viscosity of oil and B20. (Viscosity decreases as the temperature increases)

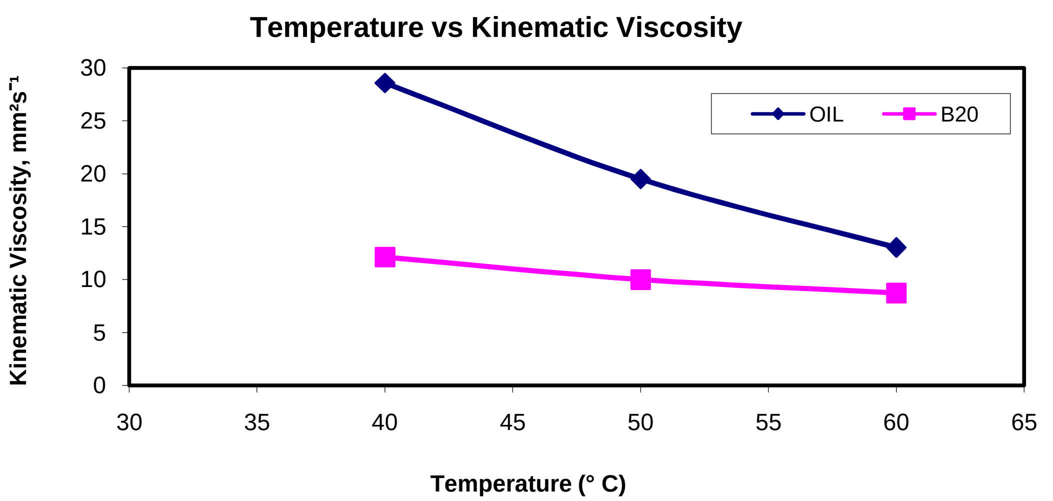

Fig. 8: Comparison of viscosity of obtained biodiesel with pongamia oil and B20

Table 1: Fatty acid composition of *Pongamia* oil (Meher *et al.,* 2004)

Fatty acid composition of Pongamia oil	Percentage (%)
Palmatic acid (C16)	11.65
Stearic acid (C18)	7.5
Oleic acid (C18:1)	51.59
Linoleic acid (C18:2)	16.64
Eicosanoic acid (C20)	1.32
Dasocasnoic acid (C22)	4.45
Tetracasanoic acid (C24)	1.09

Table 2: Physicochemical property of *Pongamia*oil (Meher *et al,*. 2004)

Chemical Properties	Values
Acid value	5.06
Sopanification value (mg KOH/g)	187
Unsoponifiable matter (w/w percent)	2.6
Iodine value (g/100g)	86.5

Table 3: Fuel Properties

S.NO	Fuel	Density	Flash Point	Fire Point
		(kg/m³)	(^{o}C)	(^{o}C)
1	Biodiesel using KOH	790	222	252
2	Biodiesel using NaOH	774.4	228	261
3	B20	811.8	148	186
4	OIL	766.2	189	224

Table 4: Effect of Temperature on Viscosity

S.NO	Temp (^{o}C)	Kinematic Viscosity		B20	Oil
		NaOH	KOH		
1	40	20.58	26.46	12.13	28.57
2	50	19.22	21.67	10	19.5
3	60	15.89	14.47	8.73	13.02

4. Conclusion:

Pongamia oil was transesterified using base catalysts: NaOH and KOH with methanol to form Biodiesel. The conversion was nearly 68% and 73% respectively for NaOH and KOH catalyzed transesterification reactions. Their fuel properties such as kinematic viscosity and flash point were determined and compared with European standards.

1) The experimental results reveal that the obtained result from base catalyzed transesterification process doesn't compare well with that of the European standards.
2) The viscosity that was obtained was more than the limits (Viscosity at 40°C by ENISO3104 ISO 3105 is 3.5-5.0 mm^2/ s and flash point 120 °C).
3) Further improvements such as using co solvents and adopting acid pre-treatment methods may improve the yield and quality of biodiesel.

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