International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume 3, Issue4 (July-August 2015), PP. 304-309

DEVELOPMENT OF NEW DIELECTRIC LIQUID FROM PONGAMIA OIL AS ALTERNATIVE FOR TRANSFORMER OIL

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Abstract— ***Dielectric liquids (edible/non-edible) are alternative innovative for mineral oil coolant commonly used in distribution and power transformers. In this work an attempt is made to improve the properties of pongamia pinnata non edible oil by esterification carried out by changing different parameters such as temperature, time and amounts of catalyst. After modification of pongamia pinnata non-edible oil different properties such pour point, flash point, moisture content, viscosity, density, acid value, Breakdown Voltage, Dielectric constant, Dielectric dissipation and Oxidation stability are determined by standard methods and compared with the standard value of mineral oil used for the transformer. The Acid value, breakdown voltage, Pour point and Flash point are found to be 0.154 mg of KOH/ g of Oil, 71.1 kV, -9 ^{0}C and 167 ^{0}C respectively which are within the comparable range. Hence, this has shown the potential of pongamia pinnata non-edible oil as a dielectric fluid and can be used in the place of standard mineral oil used as a coolant in the transformer.***

Index Terms— ***Pongamia pinnata oil, Transesterification, Dielectric liquids.***

I. INTRODUCTION

During the last 15 years the transmission situation and the performance of the transmission equipment like transformers and their insulation systems changed severely [1, 6]. Even large power transformers of several hundred MVA have to be integrated in inhabited tower blocks where issue like fire load and environmental effects become more and more important. With the worldwide growing demand for electrical energy, the environmental and safety concerns cannot be neglected. For more than one century power transformers are filled with mineral oil serving as a heat transformer and insulating medium. This oil is flammable and non biodegradable.

Therefore, significants efforts are made in quest for a more environmental friendly replacement of this petroleum based mineral oil for the transformer. Plant based materials like vegetable oil [5, 6] or its ester are gaining attention in recent times as an alternative to this mineral oil. They are nontoxic, more biodegradable and less flammable than mineral oil [2, 3]. The objective of this work is to replace the standard mineral oil of the transformer by suitable non-edible oil as dielectric liquid [4]. In the present work Pongamia pinnata oil is chosen as dielectric liquid and properties are improved by esterification process.

II. MATERIALS AND METHODS

A. Materials/Instrument used

The materials/instruments used for this work were, Mercury thermometer (range 0°C to 100°C), Heater with magnetic stirrer, Water cooled condenser, Separating Funnel, Beakers, Measuring jar, Cleveland open cup apparatus (for the measurement of flash point), Covlometer (for the measurement of moisture), Mettler Toledo (for the measurement of Acid content) and Megger meter (for the measurement of Breakdown voltage).

B. Pongamia Pinnata

Pongamia pinnata is a medium size evergreen tree which grows in Indian subcontinent and south east Australia. As per the investigation of Germplasm Resources Information Network United States Department of Agriculture, a single tree can produce 9-90 kg Pongamia pinnata seeds per year. It is a nitrogen fixing plant. This tree is fast growing, drought resistant, moderately frost hardly and highly tolerant of sanity. Historically, this plant has been used in Indian and neigh-boring regions as a source of traditional medicines, animal fodder, green manure, timber, water-paint binder, pesticide, fish poison and fuel. Recently, Pongamia Pinnata has been recognized as a viable source of non-edible oil for the biofuel industry. A Sample of Pongamia Pinnata tree is shown in Fig.1.

Fig.1: Pongamia Pinnata Tree

C. Sample Collection

Pongamia Pinnata seeds are collected from the local market of Bengaluru, Karnataka of the 2015 harvest. A sample of Pongamia Pinnata seeds along with kernel is shown in Fig.2.

Fig. 2: Pongamia Pinnata Seed along with Kernels

D. Process of Oil Extraction

The Pongamia Pinnata seeds are collected from the local market and sun dried for two days. Then, the Pongamia Seeds Kernel (PSK) is manually separated from the hull. A sample of Pongamia Seeds along with Kernel and hull is shown in Fig.3.

Fig.3: Pongamia Seeds along with the Kernenl and Hull

Then, the PSK is crushed into fine Particles and oil is solvent extracted. A sample of Pongamia Pinnata oil is shown in Fig.4.

Fig.4: Pongamia Pinnata Oil

E. Process of Esterification of Oil

A three necked Flat Bottom Flask (FBF) of 2 lit. Capacity is placed on a magnetic stirrer cum heater as shown in Fig.5. At one neck of the FBF a vertical water condenser is attached while at the other neck a thermometer is placed. 250 ml of pongamia Pinnata oil, 750 ml of methanol and 2.5 g of NaOH are added to the FBF. The central neck is closed by a stopper. Then, the magnetic stirrer is set at a speed of 800 RPM. The reaction is carried out at a temperature of 50 ^{0}C for two hrs. Thus, esterified oil is obtained. To modify the properties of esterified oil, the procedure is repeated by changing the parameter such as temperature, time and amount of catalyst.

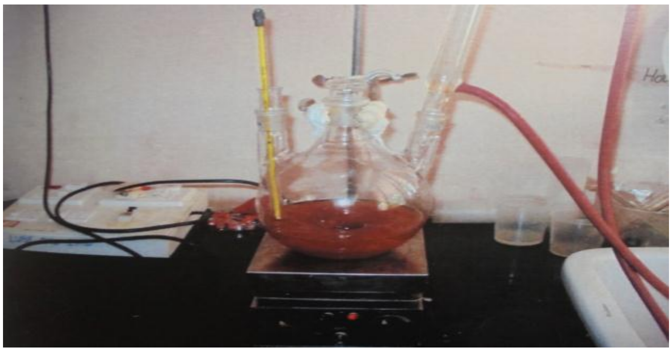

Fig. 5: Experimental Setup (FBF)

III. RESULTS AND DISCUSSIONS

A. Properties of Crude Pongamia Pinnata Oil

The properties of crude Pongamia Pinnata oil is determined by standard methods and given in the Table 1.

Table 1. Properties of Crude Pongamia Pinnata Oil

Properties (IS335)	Crude Pongamia Pinnata Oil
Pour point (^{0}C)	15
Flash Point (^{0}C)	260
Moisture Content (%)	1.01
Viscosity (CSt) at 40 ^{0}C	35
Density (g/cm^3) at 20 ^{0}C	0.894
Acid Content (mg of KOH/g Oil)	22.97
Breakdown Voltage (BDV), kV	60
Specific Resistance(ohm-cm) 90 ^{0}C	0.85x10^{12}

B. Properties of Standard Mineral Oil

The properties of Standard Mineral oil used in the Transformer as an insulator are given in the Table 2.

Table 2. Properties of Standard Mineral Oil

Properties (IS335)	Standard Mineral Oil
Pour point (^{0}C)	-6
Flash Point (^{0}C)	140
Moisture Content (%)	0.050
Viscosity (CSt) at 40 ^{0}C	27
Density (g/cm^3) at 20 ^{0}C	0.895
Acid Content (mg of KOH/g Oil)	0.03
Breakdown Voltage (BDV), kV	2
Specific Resistance(ohm-cm)90 ^{0}C	3.5x10^{12}

It is observed from the Table 1 and Table 2 that some properties like Acid content, Dielectric Strength and Specific Resistance are not matching with the properties of standard mineral oil. Therefore, the crude Pongamia Pinnata Oil need to modified by esterification process.

C. Modification of Crude Pongamia Pinnata Oil by Esterification Process at different Temperature

In this process esterification of crude Pongamia Pinnata Oil is carried out at different temperature keeping the parameters such as amount of oil, time and amount of catalyst constant. The properties of esterified crude oil are given in the Table 3.

Table 3. Properties of Esterified Crude Oil

Oil Sample (ml)	**Temperature (°C)**	**Catalyst (g)**	**Time (hr)**	**Acidity (mgKOH/g Oil)**
250	50	0.5	2	2.50
250	55	0.5	2	2.34
250	60	0.5	2	2.28
250	65	0.5	2	2.28

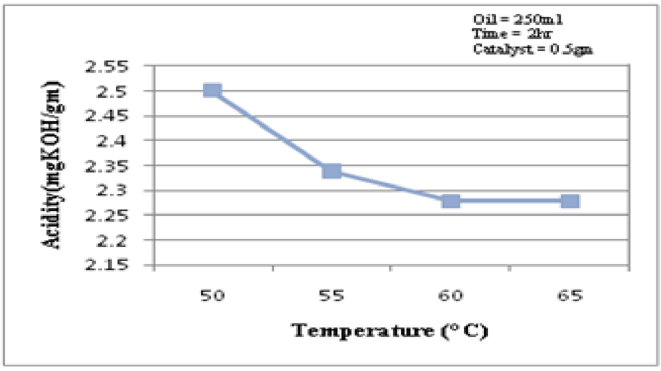

Fig 6: Effect of Temperature on Esterification

It is observed from the Table 3 that as the temperature increases Acid value of the esterified oil decreases and optimum at 60^{0}C. Further decrease in temperature, it has no affect. Therefore, next set of experiment is carried out at 60^{0}C. The effect of temperature on esterification is shown in the Fig.6.

D. Modification of Crude Pongamia Pinnata Oil by Esterification Process at different Time Intervals

In this process esterification of crude Pongamia Pinnata Oil is carried out at different time intervals keeping the parameters such as amount of oil, temperature and amount of catalyst constant. The properties of esterified crude oil are given in the Table 4.

Table 4. Properties of Esterified Crude Oil

Oil Sample (ml)	**Temperature (°C)**	**Catalyst (g)**	**Time (hr)**	**Acidity (mgKOH/g Oil)**
250	60	0.5	1	2.50
250	60	0.5	2	2.28
250	60	0.5	3	2.28

It is observed from the Table 4 that as the time increases acid value of the esterified oil decreases and optimum at 2hrs time period. Further increase in time, it has no affect. Therefore, the next set of experiment is carried out at 60^0C and time period 2hrs. This may be due to the change in colour intensity of esterified oil at longer period of time. The effect of time on esterification is shown in the Fig.7.

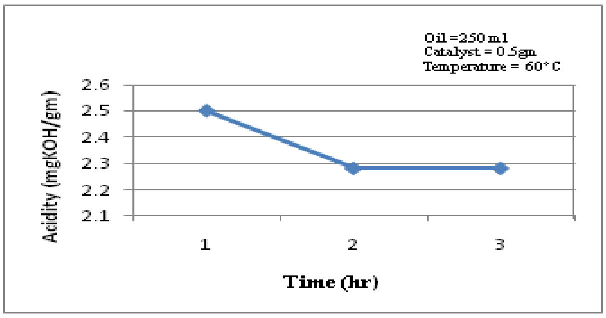

Fig. 7: Effect of Time on Esterification

E. Modification of Crude Pongamia Pinnata Oil by Esterification Process with different amount of Catalyst

In this process esterification of crude Pongamia Pinnata Oil is carried out with different amount of catalyst keeping the parameters such as amount of oil, temperature and time constant. The properties of esterified crude oil are given in the Table 5.

Table 5 Properties of Esterified Crude Oil

Oil sample (ml)	**Temperature (°C)**	**Catalyst (g)**	**Time (hr)**	**Acidity (mgKOH/g Oil)**
250	60	1	2	1.73
250	60	1.5	2	1.4
250	60	2	2	1.0
250	60	2.5	2	0.154
250	60	3.0	2	0.03

It is observed from the Table 5 that as the amount of catalyst increases acid value of the esterified oil decreases. Further increase in catalyst has no effect and reaches the minimum required acid value 0.03 for transformer standard mineral oil. The effect of catalyst on esterification is shown in the Fig.8.

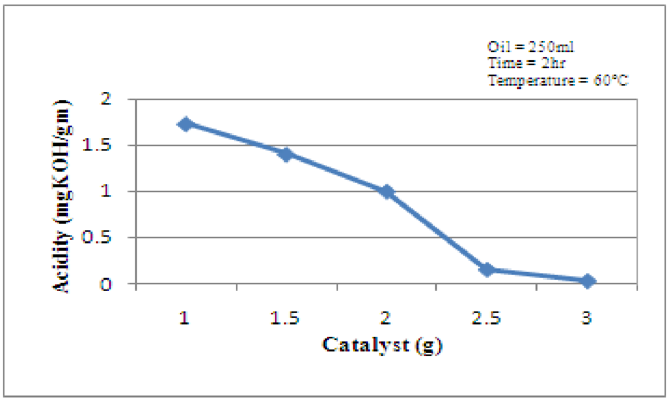

Fig.8. Effect of amount of catalyst on Esterification

F. Breakdown Voltage before and after Esterification

The Breakdown Voltage of Pongamia Pinnata oil before and after esterification is determined using standard Megger meter and given in the Table 6.

Table 6 Breakdown Voltage of Pongamia Pinnata Oil before and after Esterification

Standard time (min)	**BDV Before Esterification of Oil (kV)**	**BDV After Esterification of Oil (kV)**
2	20.0	60.8
4	18.4	82.7
6	14.0	83.1
8	26.3	73.1
10	32.3	57.9
12	21.4	68.9
Average	22.1	71.1

It is observed from the Table 6 that the average BDV of Pongamia Pinnata oil before esterification is 22.1 kV whereas after esterification the BDV is modified to 71.1 kV which is more than the standard value of 50 kV required for the Transformer oil. This is due to the fact that the characteristic of pongamia pinnata oil is improved after esterification.

G. Dielectric Constant

The Dielectric constant of Pongamia Pinnata oil after esterification is determined using LCR meter and given in the Table 7. The values are also compared with the standard value of transformer oil. It is observed from the Table7 that the dielectric constant of esterified Pongamia Pinnata oil is equally as good as mineral oil.

Table 7 Dielectric Constant of Esterified Pongamia Pinnata oil

Property	**Esterified Pongamia oil**	**Standard mineral oil**
Dielectric constant	2	2

H. Dielectric Dissipation Factor

The Dielectric Dissipation Factor of esterified pongamia pinnata oil is determined by standard method and the values are given in the Table 8. It is observed from the Table 8 that the Dielectric Dissipation Factors of pongamia pinnata oil is comparable with the standard value of mineral oil.

Table 8 Dielectric Dissipation Factor of Esterified Pongamia Pinnata oil

Property	**Esterified Pongamia oil**	**Standard mineral oil**
Dielectric Dissipation Factor	0.21	0.2

I. Specific Resistance

The specific resistance of pongamia pinnata oil after esterification is determined using standard method and given in the Table 9. It is observed from the Table 9 that the specific resistance of Pongamia Pinnata oil is closer to mineral oil.

Table 9 Specific Resistance of Esterified Pongamia Pinnata oil

Property	**Esterified Pongamia oil**	**Standard mineral oil**
Specific resistance (ohm-cm)		
1. at 90°C min.	$0.65X10^{12}$	$3.5X10^{12}$
2. at 27°C min.	$0.77X10^{12}$	$1.5X10^{12}$

J. Oxidation Stability

The Oxidation Stability of pongamia pinnata oil is determined by standard method and given in the Table 10. It is observed from the Table10 that the oxidation stability of esterified pongamia pinnata oil is comparable with the value of standard mineral oil.

Table 10 Oxidation Stability of Esterified Pongamia Pinnata Oil

Property	**Esterified Pongamia oil**	**Standard mineral oil**
1. Neutralization (mg of KOH/g of Oil) Value after Oxidation	0.56	0.4
2. Total Sludge after Oxidation	0.1	0.1

It is observed from the determined properties of esterified pongamia pinnata oil that all the values are within the comparable range of standard mineral oil. The properties are further modified by adding amine additives.

IV. Conclusion

It is concluded from the studies that acid number of pongamia oil is 22.9 mg KOH/g Oil which is brought down through esterification to 0.154 mg KOH/g Oil. Breakdown Voltage (dielectric strength) of the esterified Pongamia pinnata oil is found to be 71.1kV which is higher than the limiting value of 50kV. Dielectric dissipation of the Pongamia oil is 0.21 found to be nearer the limits of required value of 0.2 and dielectric constant is 2. The Pongamia pinnata oil has high flash point (167°C) and the pour point is reduced to -9°C by adding amine type additives of 0.2% to suite the required minimum value as per standards. Hence, it can be concluded that the pongamia oil after esterification and adding some suitable additives to it can be utilised as a natural source of transformer oil as an alternative for mineral oil.

V. ACKNOWLEDGEMENT

We thankfully acknowledge the help from Dr. Ravishankar R, Prof. G.K Mahadevaraju, Dr. Muruthy Shekhar, Prof. M.R. Rajani, Prof. B R Veena, Prof. B.S. Thirumalesh, Department of Chemical Engineering, DSCE, Bangalore. We would also like to thank Dr.D. Hemachandra Sagar, Chairman, Dr. D. Premachandra Sagar, Vice-Chairman and Dr. S.C.Sharma, Director, Dayananda Sagar College of Engineering, Bangalore for their encouragement and support for publishing this paper.

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