

# Synthesis of Bio lubricant from Bhallataka oil

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## ABSTRACT

The demand for a renewable and biodegradable lubricant as a substitute for fossil fuel-based lubricant has increased due to strong environmental concerns and expanding regulations over contamination and pollution in the environment. This study investigated the potential of using *Semecarpus anacardium* L.f. oil, which was identified as a potential raw material for biodiesel, as a feed stock for bio lubricants. Epoxidation and hydrolysis reactions were used to synthesize bio-lubricant. Epoxidized SA L.f oil was made using peroxyformic acid, which was produced on the spot by reacting hydrogen peroxide and formic acid with sulfuric acid acting as a catalyst. The oxirane value of the oil was 3.77, indicating that the unsaturated bonds were almost entirely converted to oxirane, while the iodine value decreased from 90.7 to 2.01 mg I<sub>2</sub>/g. ESAO

Keywords : Epoxidation, Bhallataka oil, Lubricants, Oxidation Stability

## I. INTRODUCTION

As the demand for energy resources are ever increasing and fossil fuel reserves are limited, there has been a growing interest in the utilization of renewable resources as an alternative to petroleum-based polymers. Consequently, much attention has been focused on the development of polymeric materials from vegetable oils, as a sustainable resource. Lubricant base stocks may be of petroleum, vegetable or synthetic nature. The most usual type of lubricant is petroleum based. Lubricants manufactured conventionally from non-renewable mineral oil resources are not biodegradable and are liable to cause

adverse environmental impacts. Vegetable oil based lubricants are environmentally preferred than petroleum based oils due to their low volatility, high flash point, favorable viscosity temperature characteristics and excellent biodegradability<sup>1-3</sup>. Vegetable oils are from renewable resource, nontoxic and lower cost alternative to synthetic fluids<sup>4, 5</sup>. In addition, vegetable oils have high solubilizing power for polar contaminants and additive molecules. However, vegetable oils have poor oxidative and thermal stability, which is due to the high degree of multiple C-C unsaturation in fatty acid chain and the bisallylic protons<sup>6, 7</sup>. Chemical modification of vegetable oils can overcome these shortcomings, by

reducing or eliminating unsaturation in vegetable oils. These changes can significantly increase the performance of a lubricant material<sup>8, 9</sup>. The improvement of lubricity properties of triglycerides upon the introduction of epoxy has also been demonstrated<sup>10, 11</sup>. Epoxidized vegetable oils and their alkyl esters are commercially useful as plasticizers and polymer stabilizers<sup>12</sup>. Due to their high reactivity of oxirane ring they can be used as intermediates in production of a variety of derivatives such as alcohols, glycols, alkanolamines, carbonyl compounds, olefinic compounds, and polymers<sup>13</sup>. The use of epoxidized unsaturated fatty acids (FA) as metal working fluids<sup>14</sup> and epoxy oils as lubricating additives to eliminate corrosion from chlorine containing compounds<sup>15</sup> is reported in literature. Epoxides can also be used as high temperature lubricants<sup>4, 11</sup> and the products obtained from ring opening can be employed as low-temperature lubricants<sup>16</sup>. Because of their commercial importance, the epoxidation of long-chain olefins and unsaturated fatty acid derivatives such as those from soybean<sup>17, 18</sup> and other plant oils like canola<sup>19, 20</sup>, rapeseed<sup>21</sup>, and linseed<sup>22</sup> are carried out on an industrial scale. Non-traditional oils like mahua<sup>23</sup>, karanja<sup>24</sup>, cottonseed<sup>25</sup>, rubber seed<sup>26</sup>, and sunflower oil<sup>27</sup> were epoxidized by using various catalysts. Earlier reports consist of research work done on epoxidation of jatropha oil is mainly on the effect of reaction temperature, concentration of reagents and time on epoxidation and reaction kinetics using different catalysts<sup>28-32</sup>. In the present study, we compare the synthesis of epoxy jatropha oil with peroxyformic acid catalyzed by sulfuric acid and its characterization for physicochemical and lubricant properties. The effectiveness of three different classes of antioxidants were investigated by using Rotating. *Semecarpus anacardium* Lf (Family: Anacardiaceae)<sup>33,34</sup> is one of the most powerful and fast acting Ayurvedic and Siddha system of medicine. Chemical and phytochemical analyses of its nut reveal the presence of biflavonoids<sup>35</sup>, phenolic compounds,

bhilawanols, minerals, vitamins and amino acids. A variety of nut extract preparations from this source are effective against many diseases<sup>36-39</sup>, viz., arthritis, tumors, and infections and so on. However, the mechanism of the pharmacological action of its nut can be greatly aided by the isolation of its active principle and determination of structure function relationship.

## II. EXPERIMENTAL

### 2.1 Materials

*Semecarpus anacardium* L.f. nuts were gathered from a field area in Kolhapur City, Maharashtra, India, which is quite close to the village of Nandgaon. The plant material specimens were identified by Dr. Vatsavaya S. Raju of the Plant Systematic Laboratory, Department of Botany, Kakatiya University, Warangal (A. P. State). The plant specimens were deposited at the Kakatiya University Herbarium, Warangal (KUW) and were identified as *Semecarpus anacardium* L.f. (syn: *Anacardium latifolium* Lam., *A. orientale* Steud.) of the Anacardiaceae. It is referred to as "nalla jeedi" in the local dialect and as "marking nut/dhobi nut" in general. Acquired from s.d. Fine Chem. Ltd. (Mumbai, India) were sulfuric acid, 30% aqueous hydrogen peroxide, sodium sulphate, and sodium methoxide; from Sigma Aldrich (St. Louis, USA) came butylated hydroxyl toluene (BHT), zinc dimethyl dithiocaramate (ZDDC), and diphenyl amine (DPA). We bought n-Hexane, methanol, and ethyl acetate (LR) from Industrial

## III. MATERIAL AND PLANT SOURCE

### Extraction and purification

Plant material: *Semecarpus anacardium* L.f. 3 kg nuts were collected, shade dried and the nuts were directly percolated with cold petroleum ether 5-6 times, filtered and concentrated by vacuum evaporation.

STEP 1: Then the nuts were made in to small pieces and percolated with petroleum ether 5-6 times, filtered and concentrated by vacuum evaporation.

STEP 2: Again the powdered nuts were percolated with hot petroleum ether 5-6 times, filtered, and concentrated by vacuum evaporation.

STEP 3: After that, the same powdered nuts were extracted with cold acetone by changing the solvent for every 3 hours in three intervals, filtered and concentrated by vacuum evaporation.

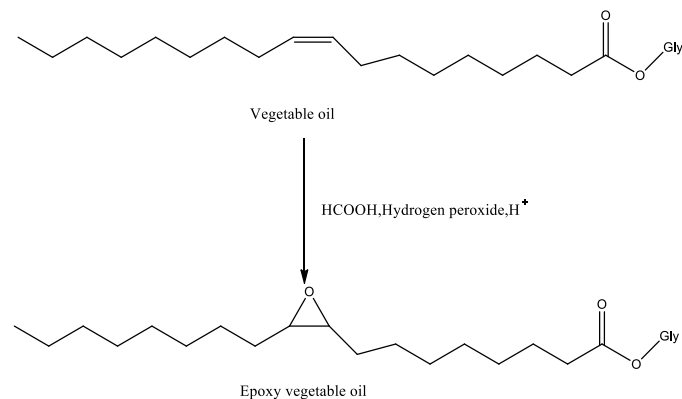
STEP 4: After cold acetone percolation, nuts were subjected to hot acetone extract, and concentrated by vacuum evaporation.

The above four concentrates were then fractionated using silica gel column with appropriate solvent gradient and the oil obtained from the fraction of HA (Hot acetone extract) 1-5 fractions, combined oil (named HA 5) was concentrated by vacuum evaporation and given for spectral analysis. Basing on UV, FT-IR, <sup>1</sup>H NMR, <sup>13</sup>C NMR, DEPT, MASS, HPLC, LCMS, GCMS, GC methods, it was found that it contains free fatty acids, triglycerides and others. Basing on spectral data and their physical properties *Semecarpus anacardium* L.f. nut oil was selected for Synthesis of Epoxy SA Oil and its Evaluation for Lubricant Properties.

## 2.2 Epoxidation of *Semecarpus anacardium* Lf Oil:

At 100°C, mechanical stirring was used to mix 500g of *Semecarpus anacardium* L.f. Oil (0.57mol), 44.5ml of formic acid (1.15mol), and 6.1ml of sulphuric acid (2%weight of HCOOH and hydrogen peroxide). Using an addition funnel, a 30% concentration of hydrogen peroxide solution (460 ml, 4.56 mol) that had been pre-equilibrated at the same temperature was gradually added to the contents over the course of two hours. Because epoxidation is exothermic, this precaution was taken to avoid overheating the system. At 600 degrees Celsius, the reaction's contents were agitated following the addition of hydrogen peroxide. Periodically, samples were taken, their oxirane value was determined, and they were connected to gas chromatography to track the reaction. The reaction

mixture was cooled and thoroughly cleaned with water to remove any remaining acid after full conversion. The separation of was carried out using ethyl acetate.



Gly is the rest of the triacylglycerol molecule

## General method for preparation of epoxy vegetable oils

Unsaturated bonds in the oil were converted into oxirane by epoxidation. ESAO exhibited superior oxidative stability compared to SAO. The lubricating properties of ESAO, epoxy Soyabean oil (ESBO) and epoxy jatropha oil EJO were comparable.

*Semecarpus anacardium* Oil :FT-IR of the compound displayed bands at 3007.22(=C-H),2925.38(C-H),2854.52(C-H),1745.89(C=O),1261.35(C-O – C(=O)),1374.35,1236.94,1163.58(C-O –C(=O)),722.60. <sup>1</sup>HNMR(CDCl<sub>3</sub>,ppm):7.26-7.28,5.24-5.42(m,OCH-CH<sub>2</sub>),4.12-4.18,4.26-4.34(dd,OCH<sub>2</sub>-CH),2.74-2.8,2.28-2.2.36(t,-CH<sub>2</sub>-C=O),1.98-2.08(m,CH<sub>2</sub>-CH=CH-),1.56-1.68,(m,CH<sub>2</sub>-CH<sub>2</sub>-CO-),1.20-1.42(m,-CH<sub>2</sub>-CH<sub>3</sub>),0.84-0.92(t,-CH<sub>2</sub>-CH<sub>3</sub>) <sup>13</sup>CNMR:173.152(-COO-),172.717,(130.111,129.922,129.740,129.620,128.008,127.819,)(-CH=CH-) 77.249,76.994,76.740,68.023(-CHO- C=O),34.119,33.961,(31.861,31.737,31.475,29.716,29.572,29.477,29.432,29.275,29.226,29.124,27.143,25.568,24.813)(-CH<sub>2</sub>). DEPT,(CDCl<sub>3</sub>,ppm 500Hz):130.170,129.981,129.797,129.679,128.069,127.884,68.890,68.702,68.317,65.022,62.403,62.082,14.101

,14.060,34.176,34.015,33.709,32.580,31.911,31.526,30.022,29.767,29.706,29.671,29.623,29.531,29.483,29.326,29.275,29.176,29.176,29.114,29.088,27.730,27.191,25.791,25.624,25.440,24.864,24.841,23.007,22.685,22.574.

**Epoxidized Semecarpus anacardium L.f Oil**

FT-IR(Kbr,cm-1) of the compound displayed bands at 3007.22(=C-H),2925.38(C-H),2854.52(C-H),1745.89(C=O),1261.35(C-O-C(=O)),1374.35,1236.94,1163.58(C-O-C(=O)),722.60.

<sup>1</sup>HNMR(CDCl<sub>3</sub>,ppm):5.24(m,OCH-(CH<sub>2</sub>)<sub>2</sub>), (4.96-4.90,4.32-4.24,4.07-4.18)(dd,OCH<sub>2</sub>-CH),3.70-3.78,2.28-2.37(t,-CH<sub>2</sub>-C=O),2.22-2.224,(2.16-2.18,2.12-2.14

is due to epoxy ring in the compound,(2.08-2.088,2.28-2.048, 2.04-2.02),(1.18-1.68)(m,-CH<sub>2</sub>-CH<sub>3</sub>),(0.946-0.96,0.966-0.968,0.82-0.92)(t,-CH<sub>2</sub>-CH<sub>3</sub>).

<sup>13</sup>CNMR: 173.137, 172.733, 130.097, 129.931, 129.635, 128.031, 127.839, 77.24,76.946, 76.708, 68.865, 61.997, 34.151, 59.8 is due to the epoxy ring, 33.949,31.854,31.479,29.767,29.673,29.565,29.507,29.442,29.320,29.305,29.117,29.009,27.160,25.586,24.792,22.669,22.510,14.082.

**FTIR:**

2925.77,2854.73,1743.97,1483.27,1377.92,1162.82,1100.62,723.57.

**GC-MS (EI, 70eV) :**

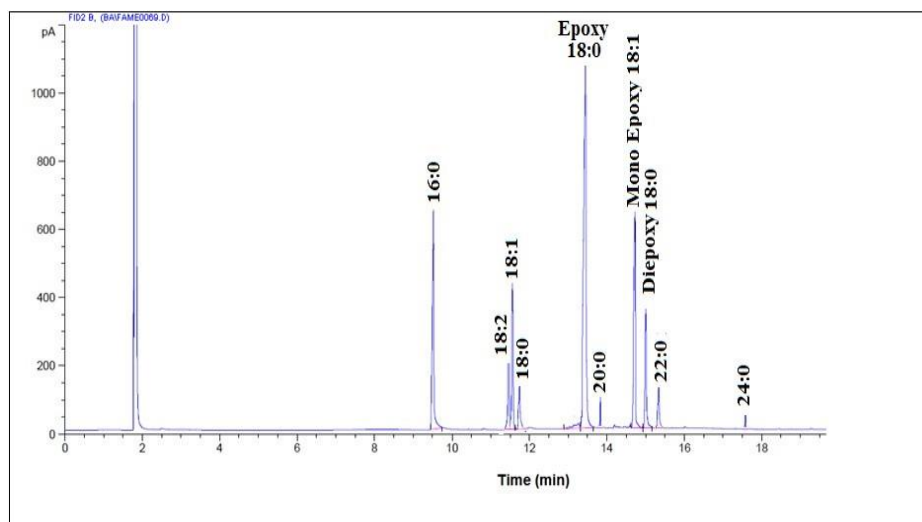


Fig.6 : GC Analysis of Epoxi Bhallataka Oil (Epoxy Shiva try acylglyceride)GC-MS (EI, 70eV)

<sup>1</sup>HNMR(CDCl<sub>3</sub>,ppm):5.24(m,OCH-(CH<sub>2</sub>)<sub>2</sub>), (4.96-4.90,4.32-4.24,4.07-4.18)(dd,OCH<sub>2</sub>-CH),3.70-3.78,2.28-2.37(t,-CH<sub>2</sub>-C=O),2.22-2.224,(2.16-2.18,2.12-2.14,(2.08-2.088,2.28-2.048,2.04-2.02),(1.18-1.68)(m,-CH<sub>2</sub>-CH<sub>3</sub>),(0.946-0.96,0.966-0.968,0.82-0.92)(t,-CH<sub>2</sub>-CH<sub>3</sub>).

<sup>13</sup>CNMR:173.137,172.733,130.097,129.931,129.635,128.031,127.839,77.242,76.946,76.708,68.865,61.997,34.151,33.949,31.854,31.479,29.767,29.673,29.565,29.507,29.442,29.320,29.305,29.117,29.009,27.160,25.586,24.792,22.669,22.510,14.082.

**2.3 Transesterification of Epoxidized Semecarpus anacardium L.f Oil:** Epoxidized Semecarpus anacardium oil ( 5.0 g ) and sodium methoxide ( 0.05 g, 1 wt% ) were dissolved in 15 mL methanol were magnetically stirred at 60-65°C. The formation of methyl esters was monitored by TLC using solvent system n-hexane/ethyl acetate ( 90:10v/v ) . After completion of the reaction, the solvent was removed in vacuo using a rotary evaporator and the resultant oil was dissolved in ethyl acetate. After washing with water the organic phase was dried ( Na<sub>2</sub>SO<sub>4</sub> ) , filtered, concentrated in vacuo, and placed under vacuum to afford epoxy jatropa fatty acid methyl esters (4.7 g )

Fatty acid Composition	16:0	18:0	18:1	18:2	18:0 Epoxy	18:1 Mono epoxy	18:0 Di Epoxy	20:0	22:0	24:0
%	12.88	4.70	9.6	6.72	37.71	12.22	7.56	1.85	4.64	2.12

**Table 4 :** Fatty acid Composition of Epoxy Bhallataka Oil

#### 2.4 Analysis

The fatty acid composition of the oil was analyzed by using gas chromatograph 6890N series of Agilent make using HP 1 column (i.d. 0.25 mm, length 30 m). The injector and flame ionization detector were at 300°C. The oven temperature was programmed at 150°C for 2 min and then increased to 300°C at 8°C/min. The carrier gas used was nitrogen at a flow rate of 1.5 mL/min. The GC-MS analysis were recorded using Agilent 6890 gas chromatograph with HP-1 MS capillary column (30 m×0.25 mm×0.5 µm) connected to Agilent 5973 mass spectrophotometer at 70 eV ( $m/z$  50-600; source at 230°C and quadruple at 150°C) in the EI mode. The iodine values of SAO (Semecarpus anacardium oil), SBO (soybean oil), JO (Jatropha oil), ESAO (epoxy Semecarpus anacardium), ESBO (epoxy soybean oil) and EJO (epoxy Jatropha oil) were determined using the AOCS Cd 1-25 standard method. The oxirane and hydroxyl values were determined using the AOCS Cd 9-57 and Cd 13-60 standard method. Quantitative analyses were always carried out in three replicates.  $^1\text{H}$  NMR spectra were obtained using a Bruker AR X 400 Spectrometer (400, 500 MHz).  $^{13}\text{C}$  NMR spectra were recorded in  $\text{CDCl}_3$  on a Varian Spectrometer (400, 500 MHz). IR spectra were recorded on a perkin Elmer (model: Spectrum BX; Connecticut, USA) FT-IR Spectrometer neat as thin film.

#### 2.5 Determination of lubricant properties

Density was determined by Anton Paar DMA 4500M density meter. Kinematic viscosity of the products was measured using Cannon Fenske viscometer tubes in a Cannon Constant Temperature Viscosity Bath (Cannon Instrument Co., State College, PA) at 40 and 100°C temperature as per the ASTM method D-445. Viscosity index was calculated using ASTM method D-2270. The viscosities were average values of three determinations. Pour points were determined using Automatic Pour Point Tester manufactured by Dott. Gianni Scavini & Co., Italy. Pour points were determined by ASTM method D-97 with an accuracy of  $\pm 3^\circ\text{C}$  and the temperature was measured in  $3^\circ\text{C}$  increments at the top of the sample until it stopped pouring. All the runs were carried out in duplicate. Flash point of the products was determined using Koehler Inc. apparatus as per ASTM D-93 method. Each sample was run in duplicate and the reported average values. Rotating Bomb Oxidation Tests (RBOTs) were carried out as per ASTM Test Method D-2272 in the presence of copper catalyst at 150°C in dry conditions. In RBOT, the vessel is sealed, charged with oxygen to 90 psi pressure, and rotated axially in a constant temperature oil bath set at 150°C. The pressure in the bomb is continuously recorded. The RBOT time

is the time at which the pressure of the bomb has dropped by 25 psi. Three different commercial antioxidants namely butylated hydroxy toluene(BHT), zinc dimethyl dithiocarbamate(ZDDC), and diphenyl amine (DPA) were added to ESAO at 0.5 and 1% concentrations. And the ability of the antioxidants to resist oxidative deterioration at elevated temperature along with SAO and ESAO was carried out employing RBOT. Corrosiveness of the products was determined by ASTM method D-130 using Koehler Inc. apparatus. A polished Cu strip was immersed in 30 mL of the sample being tested at 100°C for 3 h. After 3 h, the Cu strip was removed washed and the color and tarnish level were assessed against the ASTM Copper Strip Corrosion Standard.

**Thermo mechanical Characterization of Cured films:**

The DSC analysis was carried out with a Q100 machine from TA Instruments, USA. The heating rate used was 10°C/min in N2 atmosphere. Thermogravimetric analysis of the sample was conducted on TA Q500 instrument at a heating rate of 10°C /min in N2 atmosphere to study the effect of adding ESAO on the thermal stability. The viscoelastic properties of the cured system were evaluated using a dynamic mechanical thermal analyzer (DMTA model, Mark IV, Rheometric Scientific) at a fixed frequency of 1 Hz. The heating rate used was 3°C/min using liquid nitrogen for subambient conditions. Dynamic storage modulus, loss modulus and loss factor were obtained in rectangular tension mode for the sample size of 10×8×0.25mm.

**IV. RESULTS & DISCUSSION**

Tri glyceride oil from *Semecarpus anacardium* is composed of the unsaturated fatty acids, oleic acid 46.6% linoleic acid 29.2% along with the saturated fatty acids Palmitic acid 12.0%, Stearic acid 4.9%, Arachidic acid 1.5%, Paulinic acid 1.0%, Behenic acid 3.4%, Lignoceric acid 1.5% and the structure is schematically represented in Figure 1

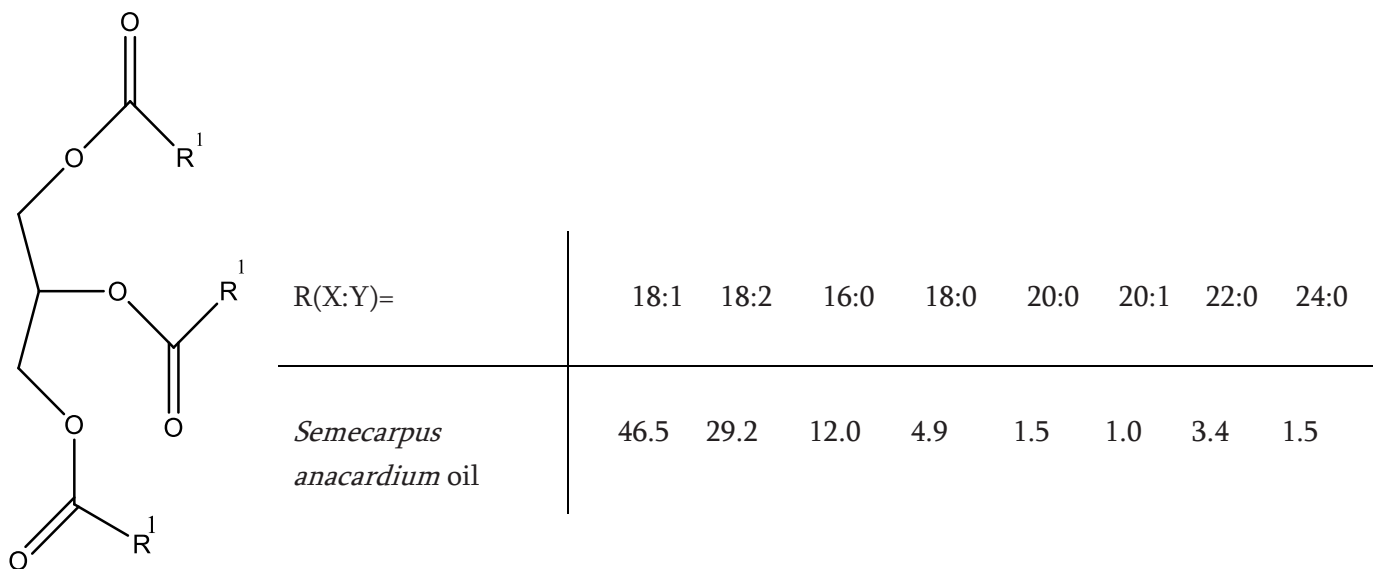


Fig 1 Chemical structure of triglyceride and typical composition of *Semecarpus anacardium* oil in % (R(X:Y)=composition of the fatty acids; x=chain length of carbon atoms; y=number of double bonds); R≠R<sup>1</sup>

Having 90.7 iodine values was epoxidised using peroxyformic acid generated *in situ* by reaction of formic acid with hydrogen peroxide in presence of sulfuric acid with 96% of conversion. Similar procedure was used for epoxidation of soybean oil. Both the reactions were monitored by analyzing the OVs. The maximum OV obtained for ESAO is 5.0% after 2 h, in case of ESBO 6.6% after 5 h. Due to lower content of unsaturated fatty acids ESAO has lower oxirane content compared to ESBO and EJO<sup>31</sup>. The infrared spectrum of ESAO Epoxy ring opening reaction and the formation of diols did not occur in the epoxidation, as evident from the absence of absorption peak at 3300-3450 cm<sup>-1</sup>. The <sup>1</sup>H NMR spectrum of ESAO indicated almost complete conversion of the carbon-carbon double bonds by the absence of the characteristic peaks of olefinic and allylic hydrogen atoms at 5.3-5.4 and 1.95-2.05 ppm respectively. Peaks in the region of 2.8-3.1 ppm indicate the presence of epoxy group protons. The peak at 1.5 ppm corresponds to the presence of methylene group next to epoxy band while the peak at 1.7 ppm corresponds to methylene group sandwiched between two epoxy groups indicating the presence of diepoxy groups formed due to the epoxidation of linoleic acid. Absence of new peaks in the range 3.3-4.0 ppm indicated that hydrolysis and formation of diols did not occur during epoxidation. <sup>13</sup>C NMR spectrum of ESAO showed the almost complete disappearance of olefinic carbon atoms between 120-140 ppm. In addition, carbon signals at 54-58 ppm indicate presence of epoxy carbons. Peaks at 172 -173 ppm due to carbonyl carbons of triacylglycerol, 69 and 62 ppm for CH and CH<sub>2</sub> carbons of glycerol backbone confirms that glycerol fatty acid linkage is intact in the product.

Gas chromatography analysis of

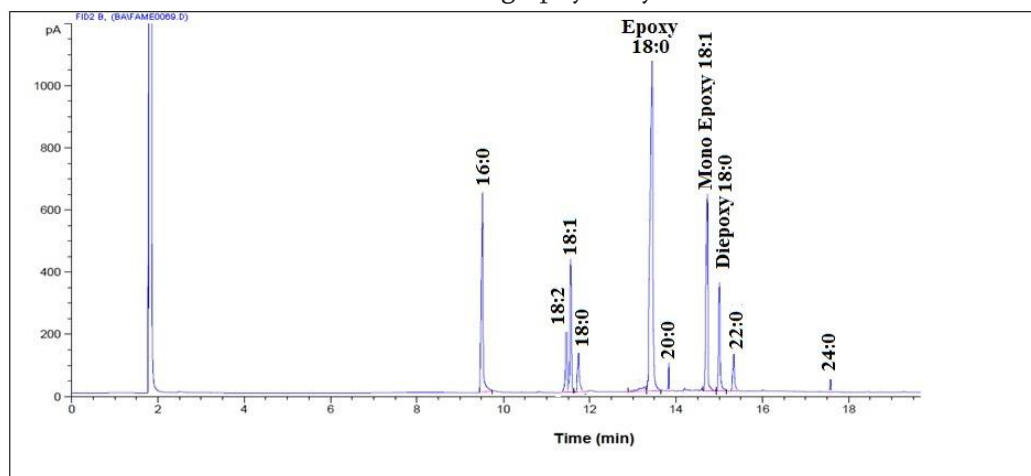
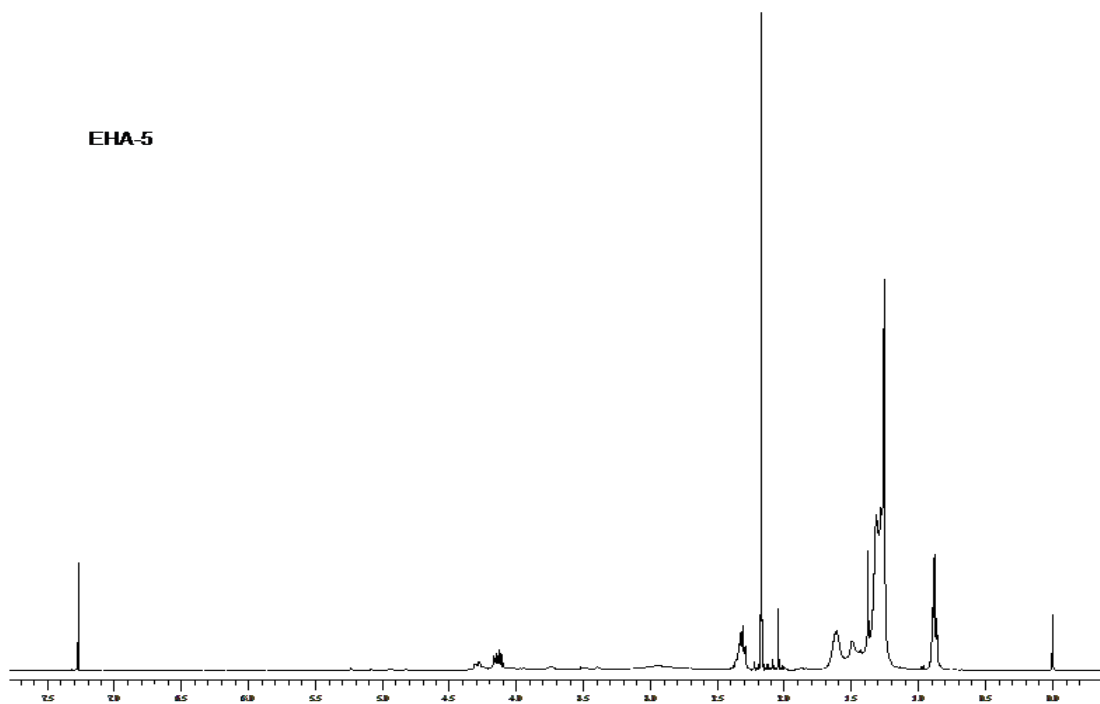
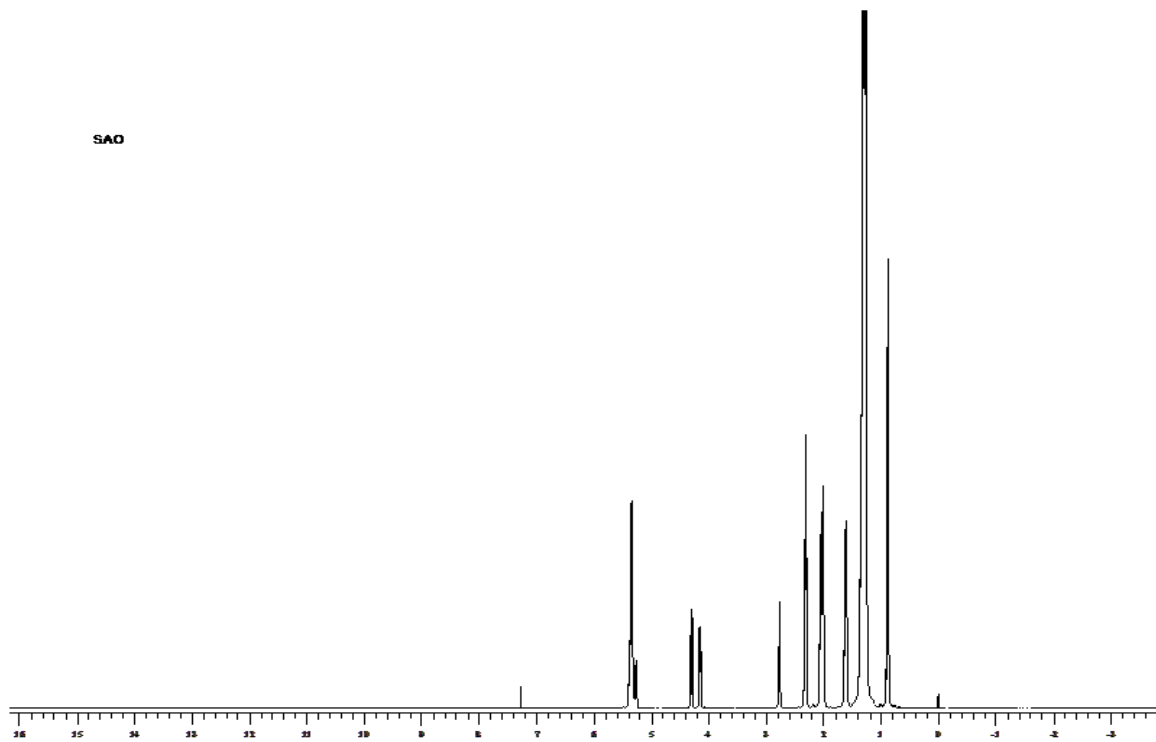


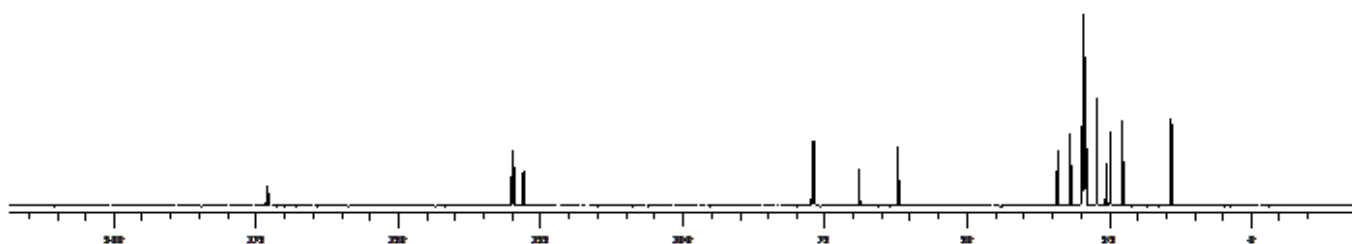
Fig.6 : GC Analysis of Epoxi Bhallataka Oil (Epoxy Shiva try acylglyceride)GC-MS (EI, 70eV)

Fatty acid Composition	16:0	18:0	18:1	18:2	18:0 Epoxy	18:1 Mono epoxy	18:0 Di Epoxy	20:0	22:0	24:0
%	12.88	4.70	9.6	6.72	37.71	12.22	7.56	1.85	4.64	2.12

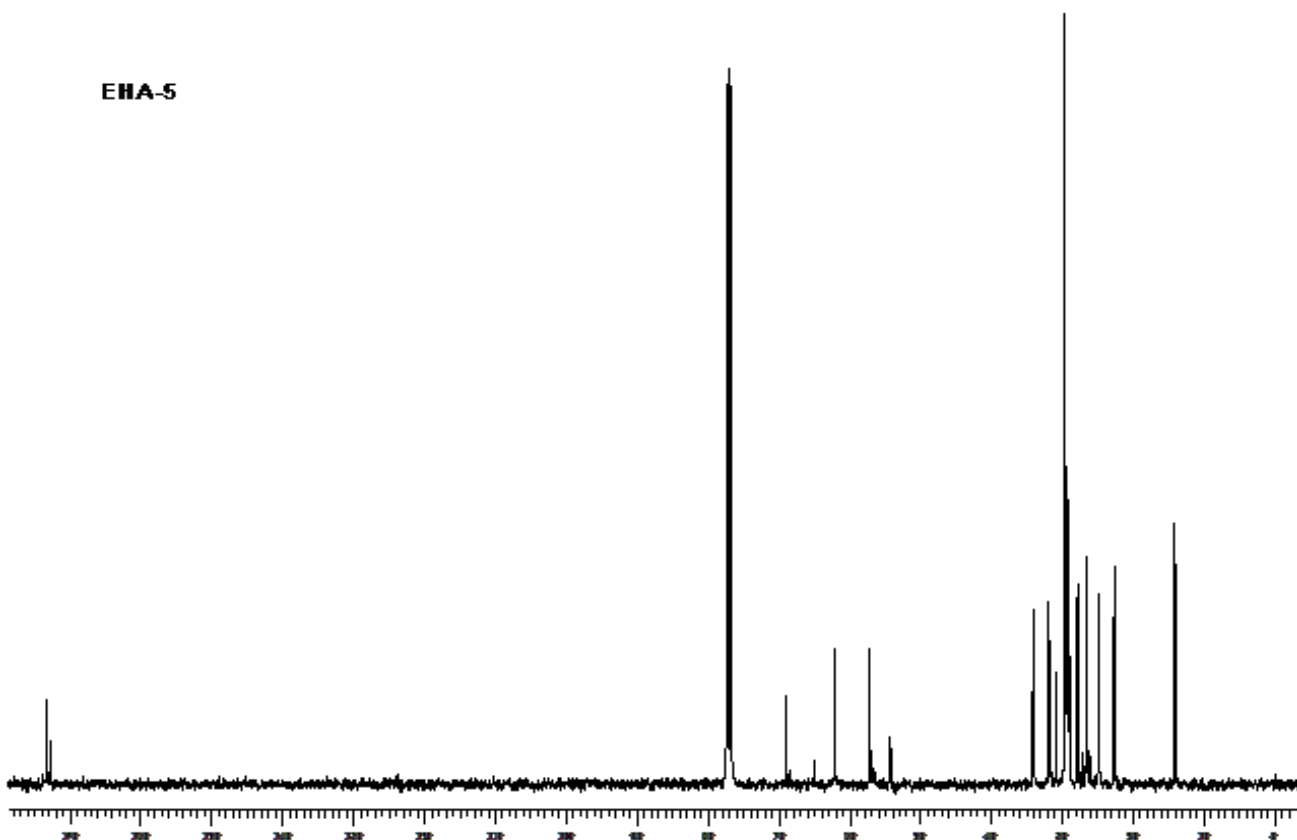
Table 4 : Fatty acid Composition of Epoxy Bhallataka Oil



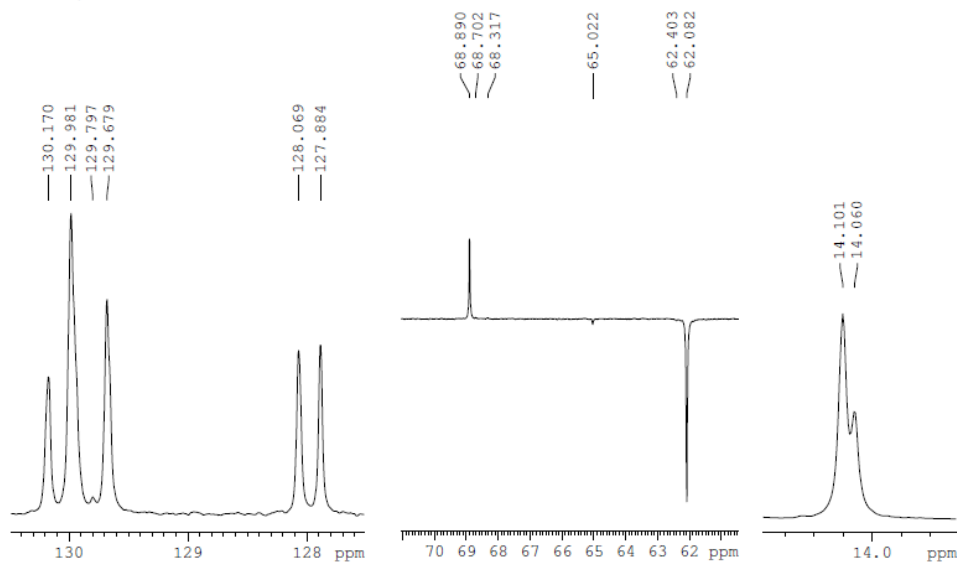




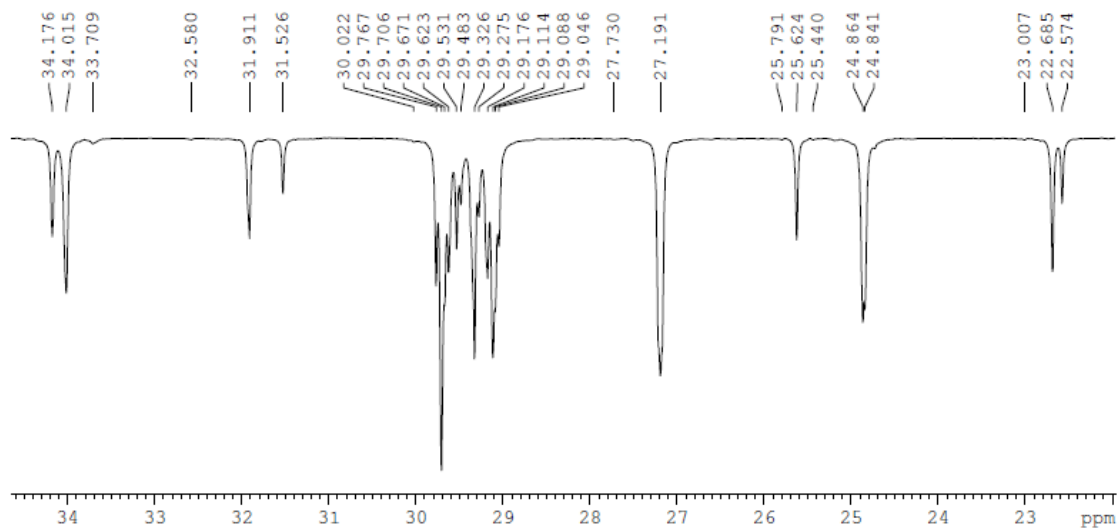
**EHA-5**



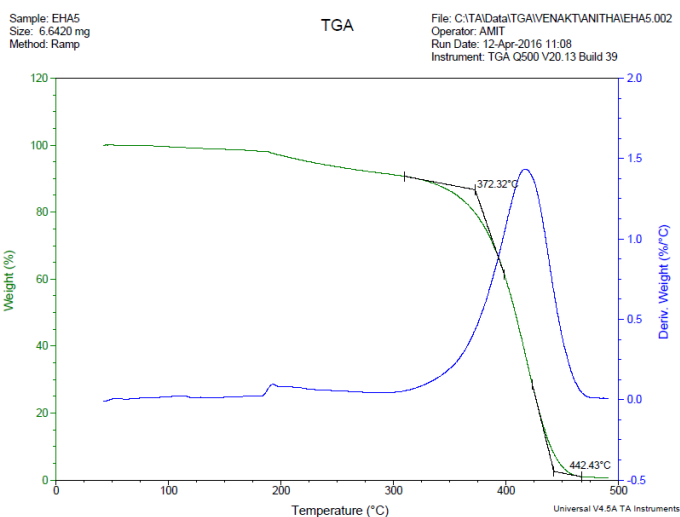
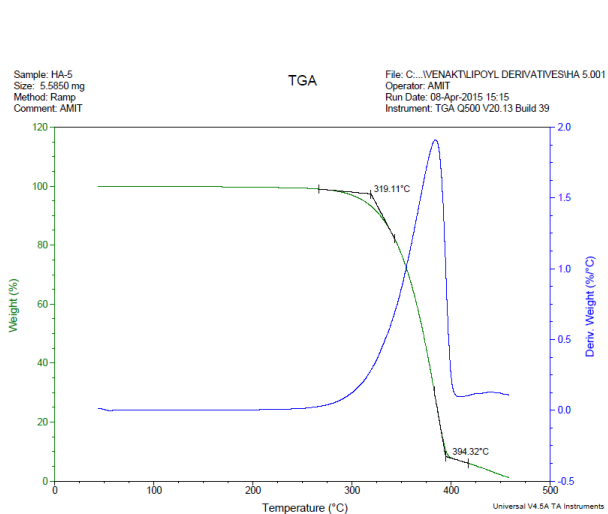
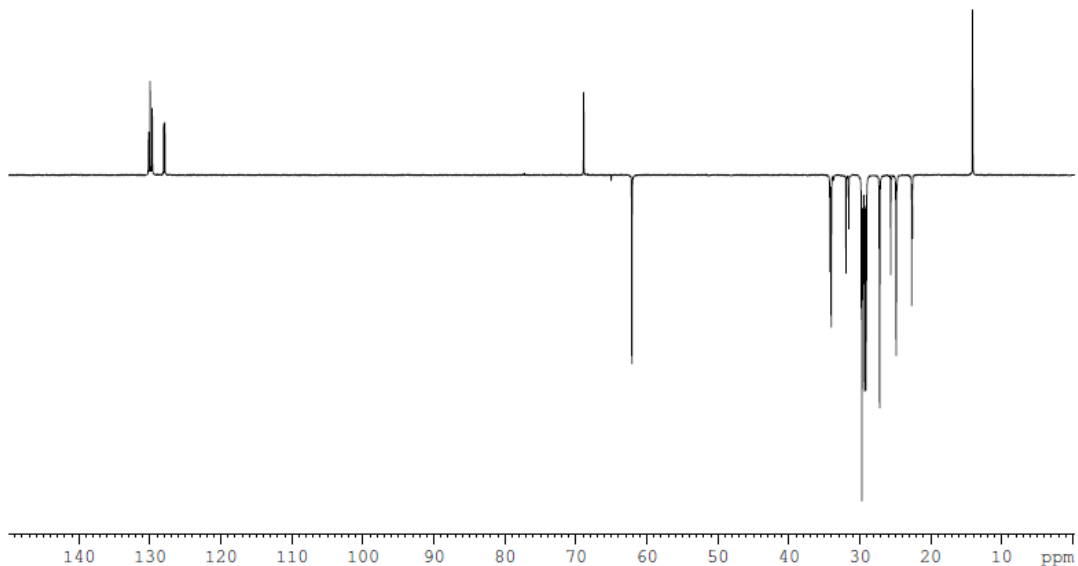
Padmavathi  
HA5 in CDCl3  
AV-500, 26-02-2016

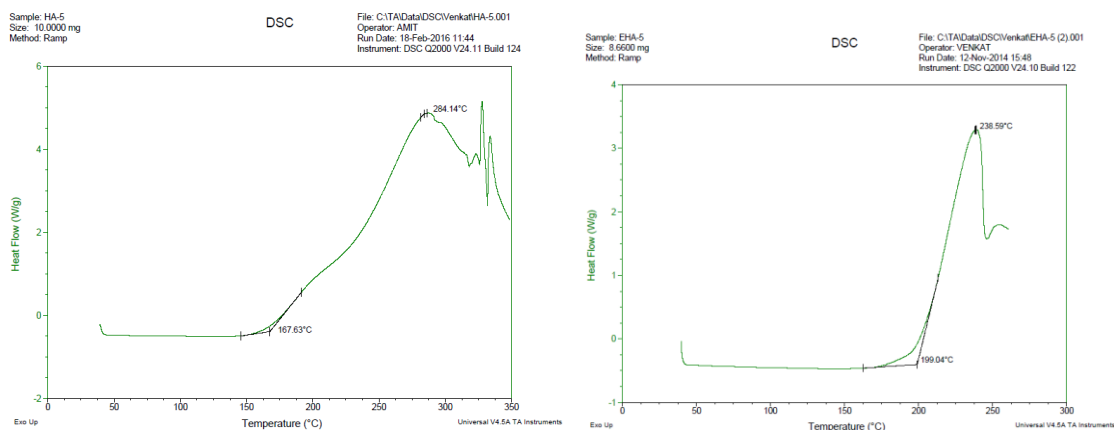


Padmavathi  
HA5 in CDCl3  
AV-500, 26-02-2016



Padmavathi  
HA5 in CDCl<sub>3</sub>  
AV-500, 26-02-2016





**Table 1: Fatty acid composition of *Semecarpus anacardium* and Epoxy *Semecarpus anacardium*(transesterified).**

Fatty acid	Composition (wt%)of BO	Composition (wt%)of EBO
Oleic acid 18:1	47.02	9.6
Linoleic acid18:2	29.38	6.72
Palmitic acid16:0	11.88	12.88
Stearic acid18:0	4.79	4.70
18:0Epoxy	--	37.71
18:1 Mono epoxy	--	12.22
18:0 Di Epoxy	--	7.56
Arachidic acid20:0	1.55	1.85
Behinic acid 22:0	3.54	4.64
Lignoceric acid 24:0	1.84	2.12

**Table 2: Physico-chemical and lubricant properties of *Semecarpus anacardium* L.f Oil and their Epoxy oils.**

Property	SAO	ESAO	EJO	ESBO
Acid value	3.22	3.37		
Iodine value	90.7	12.01	2	3
Oxirane value	---	3.77	5.0	6.6
Viscosity	29.05	127.34/14.72	18.2	136
Density 15°C	0.8981	0.9120	0.976	0.991
Specific gravity	0.9051	0.9180		
Hydroxy value wear	---	0.684		

**Table 2: Physico-chemical and lubricant properties of *Semecarpus anacardium* L.f Oil and their Epoxy oils.**

Property	BO	EBO	EKO	ERO	ESBO
Density 15°C	0.898	0.921	0.982	0.985	0.991
Acid value	3.22	0.523	-	0.653	-

Oxirane value	---	3.79	4.2	4.9	6.6	
Kinematic Viscosity (cst)	127.34 14.72	29.05 14.72	127.34 14.72	146.5 18.2	86.7 12.7	162.8 19.3
Viscosity index	-	117	144	145	136	
Pour point(°C)	-	-6	9	-12	-3	
Flash point(°C)	-	282	172	239	300	
Copper strip corrosion	-	1a	1a	-	1a	
DSC onset temperature (°C)	167	199	-	-	-	
TGA onset temperature (°C)	319	372	-	-	-	
Wear sacr dia (mm)	-	0.684	-	0.71	-	
Weldload(Kgf)	-	180		70	180	

## V. METHODS AND MATERIAL

BO:ballataka oil; EBO: Epoxy ballataka oil; EKO: Epoxy karnja oil;ERO: Epoxy rapeseed oil;ESBO: Epoxy soyabean oil.

oxirane value and was evaluated for properties namely, viscosity, viscosity index (VI), flash point, pour point, copper strip corrosion value and oxidation stability. Table 2 lists the physicochemical and lubricant properties of Semecarpus anacardiumOil , jatropha and soybean oils and their corresponding epoxy oils. Density and viscosity of epoxidised oils are more than their original oils due to their high molecular weight, more polar structure and stronger interactions between molecules<sup>11</sup>. Viscosity index of epoxy oils is less compared to their virgin oils. These epoxy oils fall under group III category of base fluids as per API classification with their VI values well above 120. Pour point of epoxy oils is expected to be higher compared to their unconverted oils due to conversion of carbon-carbon double bonds to saturated epoxy group. Epoxy oils have exhibited higher flash points compared to their unconverted corresponding oils. With its high flash point indicating low volatility, ESAO can be a potential candidate for high temperature applications.

Corrosiveness of epoxy jatropha and soybean oils (1a) found to be good. Rotating bomb oxidation test was employed to evaluate the oxidation performance of epoxy jatropha and soybean oils and their unconverted oils. As expected oxidation stability improved in the case of both the epoxy oils as a result of the reduced number of carbon-carbon double bonds in the product with increase in RBOT value of 5 min for unconverted oils to 20 min. The antioxidant DPA exhibited better performance compared to BTH and ZDDC in

## VI. CONCLUSIONS

The epoxidation of Semecarpus anacardium oil was performed resulting in high reaction conversion of 96%. The spectroscopic and gas chromatographic data indicate that nearly entire C-C unsaturation in Semecarpus anacardium oil was converted to epoxy group. ESAO exhibited better oxidative stability compared to that of virgin JO and its oxidation stability was further improved by using different antioxidants. DPA was found to be the most effective antioxidant for ESAO at 1% concentration increasing the RBOT value of ESAO about eight fold. In general, epoxidation improved all the lubricant properties

except pour point. EJO exhibited comparable or better lubricant properties compared to ESO. ESAO could be a potential lubricant base stock for high temperature Applications.

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