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International Journal of Pharmaceutical and Biological Science Archive 1 (1) 2013, 61-70

RESEARCH ARTICLE

EPOXIDATION IN KARANJA OIL FOR BIOLUBRICANT APPLICATIONS

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Received 28 June 2013; Revised 05 July 2013; Accepted 15 July 2013

ABSTRACT
Vegetable oils are perceived to be alternatives to mineral oils for lubricant base oils because of certain inherent technical properties and their biodegradability. Vegetables oils with high oleic contents are considered to be the best alternative to substitute conventional mineral oil-based lubricating oils and synthetic esters. This paper mainly reveals about extraction of oil from dry karanja seeds and study of its composition, physico-chemical properties and lastly its modification into triesters to improve the oxidation and cold flow behavior. Here, we report the oxirane ring opening of epoxidized karanja oil using behenic acid and *p*-toluenesulfonic acid (PTSA) as catalyst followed by esterification reaction with octanol and 2-ethylhexanol to form diesters. The remaining free hydroxyl group was reacted with oleic and stearic acid to give triesters. The oil before modification has viscosity index, pour point and flash point of 172, -9^{0}C and 212^{0}C and after modification it was 194cp, -36^{0}C and 307^{0}C respectively, which can be easily used as metal working lubricant, hydraulic fluid turbine oil, refrigeration oil and food processing lubricant. The structures of the products were confirmed by FTIR, ^{1}H- and ^{13}C-NMR.

KEY WORDS: Biolubricants, Biodegradability, Karanja oil, Epoxidation, Oxidation stability.

INTRODUCTION:

A critical appraisal is made of the applications of vegetable oils, the fatty esters complex and synthetic esters as rapidly biodegradable and non-toxic lubricants and fuels in the developed countries of America, Europe, and Asia [1]. As the stock of fossil fuels diminishing, throughout the world and demands for energy based comforts and mobility ever increasing, so there is a need to increase bio lubricant production, bio lubricant is an alternative lubricant different from mineral oil lubricant as it is prepared from non-conventional energy resources and is non toxic, biodegradable and eco friendly. India has great potential for production of bio lubricant from non-edible oilseeds. The promising non-edible sources in India are Pongamia pinnata (Karanja), Melia azadirachta (Neem), Madhuca indica (Mahua), Linseed (Linium usitatissimum), Castor oil (Ricinus communis), and Rice Bran oil (Oryza sativa). Bio lubricants are being given serious consideration as potential sources of energy in the future, particularly in developing countries like India. Increasing environment awareness and the desire to preserve endangered species, which were indiscriminately killed for their oils and fats [2, 3]. Over 60% of the lubricants are lost to the environment [4].There is an increasing concern for environmental pollution from excessive petroleum based lubricants use and their disposal especially in lost lubrication, military applications, and in outdoor activities such as forestry, mining, railroads, dredging, fishing and agriculture hydraulic systems [5]. The country is endowed with more than 100 species of tree born-edible oil seeds occurring in the country [6]. Vegetable oils with high oleic content are considered to be potential candidates to substitute conventional mineral oil-based lubricating oils and synthetic esters [7]. Vegetable oils are preferred over synthetic fluids because they are renewable resources and cheaper [8]. Furthermore, vegetable oils lubricants are biodegradable and non-toxic, unlike conventional mineral-based oils [9].They have very low volatility due to the high molecular weight of the triacylglycerol molecule and have narrow range of viscosity changes with temperature. Polar ester groups are able to adhere to metal surfaces, and therefore, possess good boundary lubrication properties. In addition, vegetable oils have high solubilizing power for polar contaminants and additive molecules [10]. Biodegradable greases [11] are good candidates for food-processing and water-management machinery. On the other hand, vegetable oils have poor oxidative stability primarily due to the presence of bis allylic protons and are highly susceptible to radical attack and subsequently undergo oxidative degradation to form polar oxy compounds. This phenomena result in insoluble deposits

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and increases in oil acidity and viscosity [12]. Vegetable oil also shows poor corrosion protection. The presence of ester functionality renders these oils susceptible to hydrolytic breakdown [13]. Therefore, contamination with water in the form of emulsion must be prevented at every stage. Low temperature study has also shown that most vegetables oils undergo cloudiness, precipitation, poor flow, and solidification at $-10^{0}C$ upon long-term exposure to cold temperature [14] in sharp contrast to mineral oil-based fluids. These physical and chemical properties can be improved either using genetically modified oils or chemically modified oil with suitable combination of additives [15].Plant species, which have 30% or more fixed oil in their seeds or kernel, have been identified [16].Traditionally the collection and selling of tree oilseeds was generally carried out by poor people for use as fuel for lightening. Presently there is an extended use of these oils in soaps, shampoos, varnishes, bio lubricants, candles, cosmetics, biodiesel, etc. However, the current utilization of non-edible oilseeds is very low.

1. **Biolubricant:**

Lubricants act as an antifriction media, easing smoother working,cutting down the risks of undesirable frequently encountered failures and maintaining authentic machine operations. Lubricants are essential for lubrication, heat transfer, power transmission and corrosion protection in machinery in general. Lubricants consist of a mixture of base oils with various additives, which can act to improve some of their properties. The basestocks may be of petroleum, vegetable or synthetic nature. Mineral oils are derived from petroleum and represent about 95% of the lubricants market in the world. The final composition of the lubricant may have 60-99% of base oils and the remaining as additive, depending on the desired performance. The chief characteristic [17] of a lubricant is its viscosity, since this is what prevents contact between the bearing surfaces. Other significant elements used to select a lubricant are compatibility, toxicity, chemical stability, corrosiveness, flammability, environmental effects, availability, temperature stability and price [18].

Annually, 40 million tonnes of lubricants are consumed worldwide, to be used in everything from car engines to office chairs. The most usual type of lubricant is petroleum based. The fact is that, this oil may not be longer available; industries have been exploring for a cheap, renewable source of lubricant. Vegetable oils are perceived to be alternatives to petroleum oils for lubricant formulations because of certain inherent technical properties and their ability towards biodegradability. Due to environmental concerns, future lubricants must be ecofriendly and come from a renewable source.

Formulations made from vegetable based oils together with corresponding additives are usually coined "biolubricants" [19]. Recently, increasing attention to environmental issues has driven the lubricant industry toward ecofriendly products from renewable sources. The use of biodegradable and environmentally accepted lubricants from vegetable oil has increased over the past 25 years [20]. Biolubricants have been the most anticipating as they have useful physicochemical properties, but they are also have unsuitable properties that make petroleum based lubricants the evident option. A lot of development and research is being done to vegetable oils to meliorate the physicochemical properties so that they may prove to be a cheap and good substitute of petroleum based lubricants. Compared to petroleum based lubricants, vegetable oils in general possess high flash point, high viscosity index, higher lubricity and low evaporative losses [21, 22, 12]. Traditionally vegetable oils have been applied in food uses, but recent courses of action suggest their economic usefulness in industrial application.

The replacement of petroleum based lubricants with lubricants derived from vegetable oils is a very worthy and alluring objective. The lessening of dependence on non-renewable resources, reduction of greenhouse gases and increase in markets for agricultural products these all outcomes are attractive to many countries. Bio lubricant is a product, other than food or feed, substantially composed of certain biological products agricultural materials or forestry materials. The product is used in place of a petroleum based lubricant.

2. **Biodegradability:**

American society of testing and materials (ASTM) defines biodegradable as "capable of undergoing decomposition into carbon dioxide, methane, water are less later, inorganic compounds, or biomass in which the predominant mechanism is the enzymatic action of microorganisms that can be measured by standardized tests, in a specified period of time, reflecting available disposal conditions. Biodegradability (23) is the ability of matter to be decomposed by several microorganisms it can also be defined as assessing the degree of appropriateness of a specific lubricant through various biodegradability tests such as CEC-L-33-A-94. Biodegradable lubricants are less toxic and remain harmless in various applications from automotive to industrial due to their capability of maintaining maximum protection to nature and minimum health hazard to humans. They remain eco-friendly and biodegradable in its whole cycle from production to application and degradation by microorganisms .Due to biodegradable in nature they can be renewed and provide a better option with bright future aspects to be adopted as a next generation lubrication solution .They can be proved as a source of income and employment for peoples or both. Research and development is worldwide done on utilization of non edible oils for the production of biodiesel, bio-lubes, additives for lubricating oils, saturated and unsaturated alcohols and fatty acids and many other values added products .Technology for bio-lubricant such as Engine oils,2T Oils .Compressor Oils, Aviation Oil, Metal Working Fluids, Insulating Oil, Gear Oil, Hydraulic Oil, etc. are expected to be commercialized soon (24). Bio lubricants must be used in priority for all applications where there is environmental risk. Vegetable oils are by their chemical nature long chain fatty acid tri esters of glycerol (triglyceride) and provide most of the desirable lubricant properties such as good lubrication, load carrying capacity, anti-wear, high viscosity index, high flash point and low volatility (25).

3. MATERIALS AND METHODS:

1. Materials: OIL PROCESSING FROM KARANJA SEEDS:

A Karanja seed (Pongamia glabra) was brought from a local fodder shop in Dehradun, India. The seeds were grinded into fine particles and by use of n-hexane solvent; oil was extracted by the use of soxhlet apparatus. All other chemicals and reagents were sold from Central Drug House (P) Ltd, New Delhi. Extraction is one of the key processing steps in recovering oils contained in seeds. Mechanical pressing (26) is the simplest method of extraction, however, needs no extraction medium. It has been traditionally applied to the extraction of oils from oil seeds; the only equipment needed is a hydraulic press.

3.2 Extraction of Oil from Non-Edible Karanja Seeds by Soxhlet Extractor and Its Purification:

Oil extraction can be done with or without seed coat; for Karanja utilization of a mechanical de hulling system (to remove the seed coat) can increase oil yield by 10 percent.Solvent extraction methods enhances the efficiency up to 99%. In solvent extraction method generally n-hexane or n-heptane solvent is employed [27]. The seeds were grinded into fine particles and 60gms of the grinded seed was taken and a thimble was made. The soxhlet extraction method shown in fig.1 is best method regarding higher percentage yield.320 ml of n-hexane is added to thimble from above. A soxhlet apparatus is only required when the desired compound has limited solubility in a solvent, and the impurity is insoluble in that solvent. After extraction of karanja oil, solvent is removed by rotator evaporator at 50^0 C, yielding the extracted compound that is karanja oil. The development of new, efficient, and environmentally benign pathways, which can lead to new value added products, is still an area with high potential. This strategy can decrease our dependence on non-renewable, and therefore limited, resources such as mineral oil. Vegetable oils as biolubricants are preferred because they are biodegradable and nontoxic, unlike conventional mineral-based oils. Vegetable oils have different properties than mineral oils due to different chemical structures. They have very low volatility due to the higher molecular weight of the triacylglycerol molecule and a narrow range of viscosity changes with temperature. Superior anticorrosion properties of vegetable oils result from their high affinity for metal surfaces. Vegetable oils are classified as non-flammable liquids because they have high flash point values of over 300^0C. Polar ester groups are able to adhere to metal surfaces, and, therefore, possess good boundary lubrication properties. In addition, vegetable oils have high solubilizing power for polar contaminants and additive molecules. On the other hand, vegetable oils show poor oxidative stability, primarily due to the presence of bisallylic protons, and they are highly susceptible to free radical attack and subsequently undergo oxidative degradation to form polar oxy compounds. Furthermore, low-temperature studies have shown that most vegetable oils exhibitcloudiness, precipitation, poor flow properties, and solidification at -10 ◦ C, upon long-term exposure to cold temperatures. These characteristics are disadvantages of vegetable oils, in sharp contrast to mineral oil-based fluids.

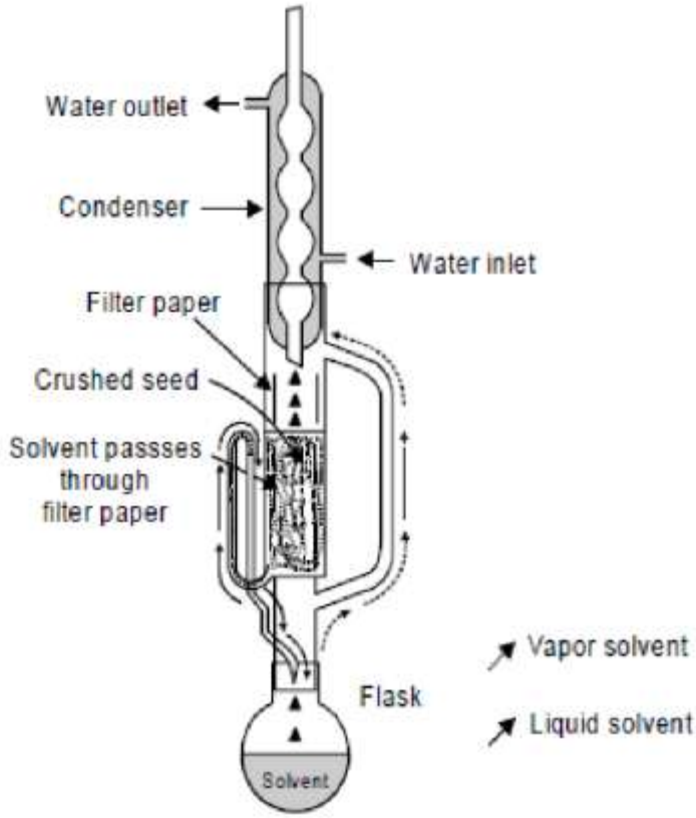

Fig. 1. Soxhlet Apparatus

The oil is used by common people due to its low cost and easy availability. The fatty acid composition of karanja oil has been reported in Table-1 [28]. The kernels contain 27-39 percent of oil [29]. The oil yield is 18-22 percent in ghanis and 24-27 percent in expellers. The fresh extracted oil is yellowish orange to brown, and rapidly darkens on storage. It has a disagreeable odour and bitter taste. Solvent extraction of expelled cake yields better quality light yellow oil. The theoretical potential of oil is estimated to be 135,000 tonnes, but the actual collection has been stagnant around 4000 to 6500 tons in the past eight years [30]. The present production of karanja oil approximately is 200 million tons per annum [31].

3.3 EPOXIDATION:

This method gives partially saturated derivatives with oxygen. Karanja seeds are good source of oleic acid as its percentage is 51.59 and are thermally stable than poly unsaturated fats, and therefore are highly desired component in vegetable oils for lubricant applications. Karanja can be successfully propagated through seeds and cuttings [31]. Modification of karanja oil through chemical processing to improve oxidation stability and low temperature fluidity is made possible by combining it with chemical additive and hence such chemical modification made to improve the cold flow behavior of vegetable oils for the use as bio lubricant base oil. Chemical modification of vegetable oils is an attractive way to solve these problems and to obtain valuable commercial products from renewable raw materials [32, 33]. The introduction of branched or bulky moieties into the structure of esters of various acids can enhance properties (for example, fluidity range) required for numerous practical applications such as bio lubricants and cosmetics. On the other hand, some compounds with bulky moieties did not significantly influence the cloud point of vegetable oil methyl esters, which would be required to improve the cold-flow properties of those esters when used as alternative bio lubricants [34]. One useful reaction for the chemical modification of oleo chemicals is epoxidation. Epoxidation methods for transforming olefinic and oleo chemical compounds have been known for many years [35] and the process has been studied [36] and patented [37]. Epoxidations, are generally performed using organic peracids formed in situ via the attack of H_2O_2 on a carboxylic acid in aqueous solution. Epoxidation of fatty acids derived from vegetable oils is an important, yet less studied, approach to producing value added material.

Table 1: Fatty acid composition of karanja oil determined by GCMS Method

The Physico-chemical properties of karanja oil are shown in the table-3 given below:

Fatty Acid	Molecular Formula	%	Structure
Palmitic Acid	C16H32O2	11.65	CH3(CH2)14COOH
Stearic Acid	C18H36O2	7.5	CH3(CH2)16COOH
Oleic Acid	C18H34O2	51.59	CH3(CH2)14 (CH=CH)COOH
Linoleic Acid	C18H32O2	16.64	CH3(CH2)12 (CH=CH)2COOH
Eicosanoic Acid	C20H40O2	1.35	CH3(CH2)18COOH
Dosocasnoic Acid	C22H44O2	4.45	CH3(CH2)20COOH
Tretracosanoic Acid	C24H48O2	1.09	CH3(CH2)22COOH
Residual		6.83	

Table 2: Physico-chemical properties of karanja oil

Characteristics	Karanja Oil
Kinematic Viscosity, cST 40°C 100°C	 43.42 8.35
Viscosity Index	172
Iodine Value	78
Saponification Value mgKOH/gm	179
Acid Value mg KOH/gm	22
Pour Point°C	-9

3.4 Synthesis of Epoxidized Oleic Acid (1):

Hydrogen peroxide solution (30% in H_2O, 9 ml) was added slowly into stirred solution of oleic acid (90%, 10gm) in formic acid (88%, 9 ml) at 4^0C (ice bath). Then the reaction proceeds at room temperature with vigorous stirring (900rpm) until formation of a white, powdery solid was noticed in the reaction vessel for 2-5 hours. The solid was collected via vaccum filteration, washed with water (chilled, 3 x 10ml), and placed for 12 hrs under vaccum to provide epoxidized oleic acid as a colorless, powdery solid.

3.5 Synthesis of 9(10) hydroxy-10(9)-behnyloxystearic Acid (2):

Epoxidized oleic acid (1, 31gm) and 5gm of PTSA by dissolving it in toluene in 250ml three-neck flask equipped with a cooler, dropping funnel and thermometer. The mixture was kept at 50^0C. Behenic acid (6gm) was added during 1.5 hrs in order to keep the reaction mixture temperature under $70\text{-}80^0C$. The reaction mixture was subsequently heated to $90\text{-}100^0C$ and refluxed for 3 hrs at this temperature range. After reaction termination, the heating was stopped and the mixture was left to stand overnight at ambient room temperature. The mixture was then washed with water, the organic layer was dried over anhydrous magnesium sulfate and the solvent was removed using vaccum evaporator to give the desired product.

3.6 Synthesis of Alkyl 9 (10)-hydroxy-10 (9)-behnyloxysterate (3 and 4):

Sulfuric acid (conc.H_2SO_4, 10 mol %) was added to a solution of 9(10)-hydroxy-10(9)-acyloxystearic acid (2,1gm) in either 3.35 ml octanol or 3.35 ml 2-ethylhexanol. The suspension was heated with stirring at 60^0C for 10 hours. Hexanes (5ml) was then added, and the solution was washed with $NaHCO_3$ (sat. aq., 1x 0.5 ml) and brine (2x1ml), dried 9($MgSO_4$), filtered, concentrated and placed under vaccum for 6-7 hours to yield the desired compounds of (3) and (4), respectively.

3.7 Synthesis of Modified Triesters (5 and 6):

To a solution of alkyl 9(10)-hydroxy-10(9)-behnyloxystrearate (3 and 4, 10gm) and sulfuric acid (10% H_2SO_4) in a two-neck round bottom flask equipped with a magnetic stir bar at room temperature; then the reaction mixture was refluxed with stirring for 10 hrs. After the reaction was transferred to a separating funnel, the lower aqueous phase was removed, and hexane (20ml) was added to the upper oily phase. The organic phase was then washed with $NaHCO_3$ (sat. aq., 2x 5 ml) and brine (2x5ml), dried 9($MgSO_4$), filtered, concentrated and placed under high vaccum for 5-6 hours to provide the trimesters (5and6).

3.8 Instrumentation:

Fourier transform infared (FTIR) spectra were recorded on a Perkin Elmer Infrared Spectrophotometer. The ^{1}H- and ^{13}C-NMR spectrum were recorded on a JNM-ECP 400 spectrometer (400MHz ^{1}H/100.61MHz^{13}C) using DMSO-d_6 as a solvent in all experiments. All the physical properties analyses were performed according to the standard methods for flash point, pour point and viscosity index. Viscosity reading is in centipoises (cp) and the unit is in mPa's (multipascal second).

3.9 RESULTS AND DISCUSSION

3.9.1 Synthesis:

Here reaction proceeds with epoxidation of oleic acid to yield epoxidized oleic acid to yield epoxidized oleic acid [38].Then the oxirane ring was opened by using behenic acid and *p*- toluenesulfonic acid (PTSA) as catalyst [39]. From above raction we get 9 (10) - hydroxy-10(9)-behnyloxystearic acid from 9, 10-epoxyoleic acid with yield 66%. Esterification of the oleic acid carbonyl was done by using octanol and 2-ethylhexanol in order to prepare alkyl 9, (10)-hydroxy-10(9)-behnyloxystearate (3 and4) with a yield 73% and 65%, respectively.

The two prepared diesters of 9, 10-hydroxy-acyloxystearic acid were used as a key for the synthesis of modified trimesters-derivatives by esterification of the hydroxyl diester groups with either oleic acid or stearic acid. The yields are summarized in Table 63

3.9.2 Infra-Red Spectroscopy:

The structures of the synthesized compounds were confirmed were confirmed using Fourier-Transformed Infrared (FTIR) spectroscopy. The characteristic signals in the FTIR spectrum of epoxidized oleic acid (1) at 830, 845cm^{-1} correspond to quaternary carbons of the oxirane ring [40] and the signals at 2987 and 2865 cm^{-1} correspond to aliphatic carbons in the molecules. In mono-ester product (2) the bands at 1738 and 1710 cm^{-1} due to C=O stretching vibrations of ester and carboxylic acid moieties confirm the success of oxirane ring opening step. Furthermore, the most characteristic evidence confirms trimester formation was the disappearance of OH stretching vibration around 3400 cm^{-1}. Other characteristic FTIR data are summarized in Table 3.

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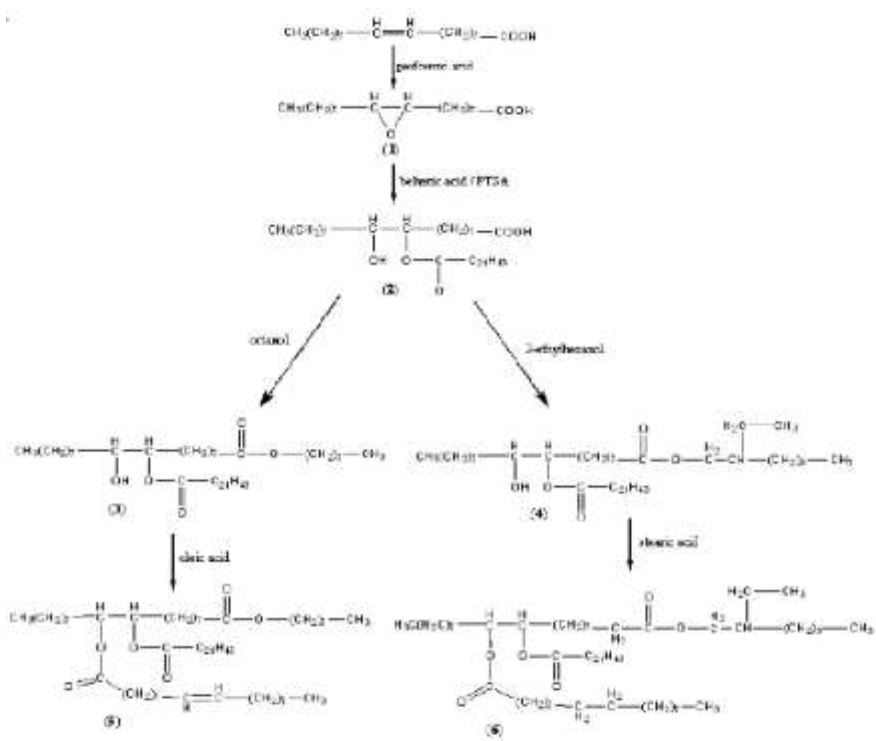


Figure 2: Synthesis for Compound 1-6

Table 3: Characteristic FTIR absorption data of compounds (1-6)

compound	ν (O-H)	ν (C-H) aliphatic	ν (C=O)	ν(-C-O-C)
1	3425	2987, 2865	1708	830, 845
2	3441	2946, 2872	1738, 1710	-
3	3453	2947, 2822	1730	-
4	3412	2943, 2826	1727	-
5	-	2957, 2891	1733	-
6	-	2982, 2865	1734	-

3.9.4 NMR Spectroscopy:

All compounds displayed good solubility in DMSO. The nuclear magnetic resonance spectral data gave additional support for the composition of the compounds. The observed changes are evidences of the reaction had happened because the chemical shift of a compound is heavily depended on its electronic environment. The ^{1}H-NMR spectra of the trimester compounds (5 and6) confirmed the disappearance of OH signal at about 9.40-9.65 ppm. Furthermore, at about δ 2.15-3.57 ppm resonance the protons signals of the aliphatic $–CH_2–$ were appeared for the prepared compounds [41]. Other characteristic data are tabulated in table 4.

The ^{13}C-NMR data of the prepared products are presentable in Table-4. The C=O resonance group of the products appear at about 170.36-174.62 ppm. It is most likely that shift is due to the decrease of electron density at carbon atoms when oxygen is bonded to it [41]. In the case of compounds (2, 4) there are two signals while in with compounds (5 and 6) there are three signals in this range. These results were in agreement with the proposed structures which given to these compounds.

Table 4: ^{1}H-NMR spectral (δ, ppm) data of prepared products

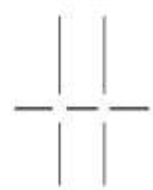
compound	$-CH_3$	CH_2 aliphatic		CH=CH-	O-H
1	1.13-1.54	2.30-3.52	4.50-5.37	-	8.55
2	1.24-1.62	2.28-3.57	4.47-5.40	-	8.51, 9.25
3	1.53-1.76	2.15-3.52	4.53-5.40	-	8.52, 9.32
4	1.23-1.80	2.40-3.53	4.32-5.35	-	8.40, 9.34
5	1.21-1.53	2.37-3.56	4.42-5.44	5.29, 5.63	-
6	1.19-1.67	2.31-3.55	4.50-5.41	-	-

Table 5: ^{13}C-NMR spectral (δ, ppm) data of prepared products

compound	$-CH_3$	$-CH_2-$		-CH=CH-	C=O
1	22.56-24.34	26.56-41.30	60.67, 62.53	-	172.67
2	21.32-24.78	26.45-40.65	60.62, 62.55	-	171.43, 174.62
3	22.67-24.87	26.43-40.51	60.60, 62.54	-	170.86, 173.56
4	20.85-24.11	26.50- 40.34	60.56, 62.50	-	170.86, 173.56
5	22.35-25.12	26.51-40.54	60.56, 62.47	62.42, 64.32	171.43, 173.14, 174.08
6	22.50-24.52	26.45-40.28	60.57 62.53	-	171.54, 172.48, 174.60

4. **Effect of chemical Modification on Physical properties:**

There is an important fact in determining how well oil will behave as a potential lubricant is to evaluate the pour point (PP). The low temperature flow property of vegetable oils is extremely poor and this limits their use at low operating temperatures especially as automotive and industrial fluids. In the high oleic oils removal of polyunsaturation (low usaturation numbers) results in improved cold flow property due to reduction in saturated fatty acids. However, the high oleic oils are still limited in their use in low temperature applications [40].

The prepared compounds (2-6) described above were screened for low-temperature behavior through determination of both CP and PP. Modified trimester exhibited a PP of -36^{0}C (Table-6), which is an improvement over that of other compounds. As, expected, as the chain length of the ester increased, a corresponding improvement in PP is observed, which may be due to the greater ability of the longer-chain esters to more effectively disrupt macrocrystalline formation at reduced temperature. A positive effect on the low-temperature performance of the resultant products was observed when a branched alcohol, 2-ethyl hexanol, was used. For instance, compound (6) has PP of -36^{0}C, whereas compound (5) has PP of -31^{0}C. This improvement in PP is observed, which may be due to the greater ability of the branch-chain esters to more effectively disrupt macro crystalline formation at reduced temperatures.

Table 6: Pour point, Flash point, Viscosity values and Percentage Yield of prepared products

Compound	Pour point (^{0}C)	Flash point (^{0}C)	Viscosity (cp)	Yield (%0)
1.	-	140	-	72
2.	-	232	-	64
3.	-23	142	129	73
4.	-28	165	149	65
5.	-31	176307	159	87
6.	-36		194	92

Concerns over the discharge and accumulation of lubricants and fuels on land, water and air posing serious hazards to health and deleterious effects on the environment led to the framing of increasing stringent state policies discouraging the use of conventional petroleum based lubricants in several applications such as total loss lubricants, industrial lubricants for food processing, water-management machinery, two-stroke engine lubricants, etc. and encouraging their replacement with rapidly biodegradable lubricants of low toxicity [42,43]. There are moves to replace mineral oil based lubricants in high powered diesel engine vehicles with low evaporation loss ester based lubricants in order to reduce particulate emissions which pose serious respiratory problems in large cities [44,45]. Vegetable oils when used as renewable raw materials for new industrial products such as lubricants have been a great importance now a day because of the emphasis on environmental friendly lubricants is large in demand due to the rapid depletion of world fossil fuel reserves and increasing concern for environmental pollution from excessive mineral oil usage. Use of pongamia oil as a lubricant can improve the efficiency, and can completely eliminate emission of metal traces as it does not contain any metal constituents in it, unlike a petroleum oil lubricant [46].

CONCLUSIONS:

In the present study, several basic trends were observed. The prepared compounds (2-6) exhibited the favorable cold-flow characteristics, as determined by PP. Compound (6) yielded the best performance with PP of -36^{0}C. The presence of branching group at the head of the molecule will make it more effectively in disruption crystalline formation at reduced temperatures. These products can be efficiently utilized for bio based industrial materials, such as bio lubricants. Contaminated environment is expensive. Conventional mineral oil based lubricants are extremely harmful for the biosphere when they get into the environment. Due to poor degradability mineral oils remain in the ecosystem for a long time. Even in case of high dilution the effect will be fatal (eco-toxicological effect). Higher amount will be required for elimination of contaminated ecosystem clearly. Eco friendly hydraulic oil, refrigerator oil, gear oil, motor oil, two stroke engine oils, lubricants for food processing and water management and disposal operations and eco-friendly greases for both general purpose and multipurpose should be widely used. Eco friendly biodegradable lubricants has to be immediately introduced in the market to replace the mineral oil and other non-biodegradable products currently in use in these countries to check rampant pollution caused by these lubricants. Edible oils in use in developed nations such as USA and European nations but in developing countries the production of edible oils are not sufficient. In a country like India, there are many plant species whose seeds remain unutilized and underutilized have been tried for biodiesel production. Non-edible oil seeds are the potential feedstock for production of bio lubricant in India.

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