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Potential of Non Edible Vegetable Oils as an Alternative Lubricants in Automotive Applications

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ABSTRACT
Industrial revolution transformed the lives of human by shifting the muscle power to machines. Machine utilizes fuel for developing power and motion. Relative motion amongst the machine parts makes them susceptible to frequent wear and tear. Lubricants act as an antifriction media, facilitating smoother working, reducing the risks of undesirable frequent failures and maintaining reliable machine operations. Lubricants and lubrication have been in use since man invented machines. Discovery of abundant crude reserves and inexpensive products for the demanding lubrication requirements at the outset of industrial revolution diverted the attention from the natural products like animal fats and vegetable oils lacking competitive properties. Presently, the depletion of the world's crude oil reserves, increased oil prices and the global concern to protect the environment against pollution, exerted by lubricants and their uncontrolled disposal have brought renewed interest in the development and use of nature friendly lubricants derived from alternative sources. This paper discuss the potential of non-edible vegetable oils as an alternative source of lubricants for automotive applications.
(**Key words:** Animal Fats, Crude Oil Reserve, Environment, Lubricants, Machine, Maintenance, Oil Spillage, Vegetable Oils)

1. INTRODUCTION
Desire to excel and achieve comfort levels aided by the inquisitive approach of human being sparked Industrial Revolution. It began in the United Kingdom, and then subsequently spread throughout Western Europe, North America, Japan, and eventually to the rest of the world. Industrial Revolution is the name given to the movement during 1750 to 1850 AD in which muscle power got replaced by machines changed almost every aspect of daily life .It transformed agriculture, manufacturing, mining, transportation etc aided by technology imposing a profound effect on the social, economic and cultural conditions of the times. Most notably, average income and population began to exhibit unprecedented sustained growth.The Industrial Revolution could not have developed without machine tools, for they enabled manufacturing machines to be made. They have their origins in the tools developed in the 18th century [1]. The history of the automobile begins as early as 1769, with the creation of steam engined automobiles capable of human transport.

Although various forms of internal combustion engines were developed before the 19th century, their use was hindered until the commercial drilling and production of petroleum began in the mid 1850's [2]. By the late 19th century, engineering advances led to the widespread adoption in a variety of applications like industrial, automotive and handheld applications where engines with high specific power, simple design, light overall weight and low cost were required. The expansion of the high-temperature and high-pressure gases produced by combustion in an IC engine apply direct force to components of engine like pistons, turbine blades, or a nozzle thus moving the component over a distance, transforming chemical energy into useful mechanical energy [3]. Reliable and safer operations of an automobile at desired operating conditions requires effective lubrication of the moving parts to slide smoothly over each other. Insufficient lubrication subjects the parts of the engine to metal-to-metal contact, friction, heat build-up, rapid wear often culminating in parts becoming friction welded together e.g. pistons in their cylinders. Lubricants and lubrication have been in use since man invented machines. Natural products like vegetable oils and animal fats were used in large quantities during the early era of machines due to their ease of availability and absence of other competitive options untill 19th century. The demand of lubricants became very high afterwards because of rapid industrialisation, putting pressure on the price and availability of lubricants from vegetable and animal sources. Mineral oils were started being used as lubricating oils after the successful prospecting and extraction of mineral oils during the second half of 19th century which made available large quantities of cheap replacement for lubricants of vegetable and animal origin with desirable properties. Lubricants both fresh and used can cause considerable damage to the environment mainly due to their high potential of serious soil and water pollution. Further the additives typically contained in lubricant can be toxic to flora and fauna. In used fluids the oxidation products can be toxic as well. Lubricant persistence in the environment largely depends upon the base fluid however if very toxic additives are used they may negatively affect the persistence. The depletion of the world's crude oil reserve, increased oil prices and the demand to protect the environment against pollution exerted by lubricating oils and their uncontrolled spillage have brought renewed interest in the development and use of alternative lubricants. Vegetable oils are perceived to be alternatives to mineral oils for lubricant formulations because of certain inherent technical properties and their ability

towards biodegradability. Compared to mineral oils, vegetable oils in general possess high flash point, high viscosity index, high lubricity and low evaporative losses [4,5,6,7].Vegetable oils are extracted from plants by placing the relevant part of the plant under pressure, to squeeze the oil out. Oils (edible or non edible) may also be extracted from plants by dissolving parts of plants in water or another solvent, and distilling the oil (known as essential oils), or by infusing parts of plants in a base oil.Various researchers have proved the worth of edible vegetable oils viz. coconut oil [6], palm oil [7], soyabean oil [8], canola oil [9] to be used as ecofriendly lubricant in recent past.But in present situations harnessing the edible oils for lubricants formation restricts the use due to increased demands catering the growing population worldwide and local availability. Non edible vegetable oils and other tree borne seeds can prove to be an effective alternative, although limited research has been done on varieties like Jatropha Curcas (Ratanjyot), Jojoba, Linseed, Pongamia Pinnata (Karanja) etc. prominently for biofuel applications and needs focused attention for fulfilling the environmental friendly lubricant needs to their full potential.Castor, Mahua and Neem also possess certain properties which makes them a promising candidate for such formulations.

2. LUBRICANT

A lubricant is a substance (usually a liquid) introduced between two moving surfaces to reduce the friction and wear between them. A lubricant provides a protective film which allows for two touching surfaces to be separated, thus lessening the friction between them. Lubrication occurs when opposing surfaces are separated by a lubricant film. The applied load is carried by pressure generated within the fluid, and frictional resistance to motion arises entirely from the shearing of the viscous fluid. The science of friction, lubrication and wear is called tribology. Romans used rags dipped in animal fat to lubricate wagon wheels; however the science of lubrication (tribology) really took off with the industrial revolution in the 19th century. Lubricants are generally composed of a majority of base oil and a minority of additives to impart desirable characteristics as shown in fig.1. Typically lubricants contain 90% base oil (most often petroleum fractions, called mineral oils) and less than 10% additives. Vegetable oils or synthetic liquids such as hydrogenated polyolefins, esters, silicone, fluorocarbons and many others are sometimes used as base oils. Additives deliver reduced friction and wear, increased viscosity, improved viscosity index, resistance to corrosion and oxidation, aging or contamination ,etc.[10,11].

Lubricants perform the following key functions-

1. Keep moving parts apart
2. Reduce friction
3. Transfer heat
4. Carry away contaminants & debris
5. Transmit power
6. Protect against wear
7. Prevent corrosion

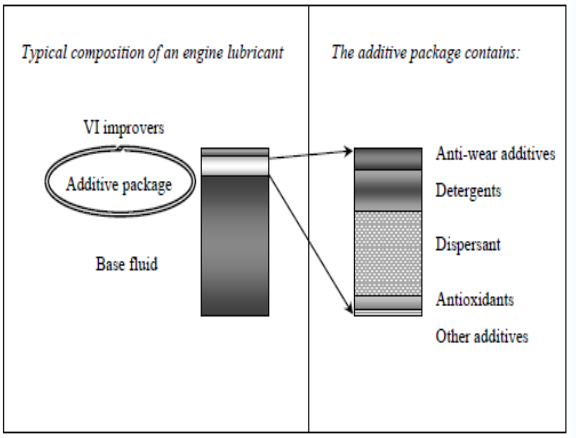

Fig.1. Composition of an Engine Lubricant

Lubricants characteristics, important and desired from the performance point of view are listed below:

1.Viscosity being the most important property is its resistance to the flow, which is directly related to the film formation that protects the metal surfaces from several attacks.

2.Viscosity Index is an arbitrary dimensionless number used to characterize the range of the kinematic viscosity of a petroleum product (ASTM D2270 method) with the temperature. Oils with values higher than 130 find a wide diversity of applications.

3.Pour Point of a liquid is the lowest temperature at which it will pour or flow under prescribed conditions. It is a rough indication of the lowest temperature at which oil is readily pumpable.

4.Cloud Point is the temperature where the mixture starts to phase separate and two phases appear, thus becoming cloudy. This behavior is characteristic of non-ionic surfactants containing polyoxyethylene chains, which exhibit reverse solubility versus temperature behavior in water and therefore "cloud out" at some point as the temperature is raised.

5.Flash Point of a flammable liquid is the lowest temperature at which it can form an ignitable mixture with oxygen. At this temperature the vapor may cease to burn when the source of ignition is removed.

6.Fire Point of a fuel is the temperature at which it will continue to burn after ignition for at least 5 seconds. At the flash point, a lower temperature, a substance will ignite, but vapor might not be produced at a rate to sustain the fire.

7.Oxidation Stability is an ability to show resistance towards oxide forming tendency which increases at incrased temperatures.

8.Neutralization Number is an Indication of the amount of acid/base content for Neutralisation.

9.Environment Compatibility is the characteristics which ensures that the fluid media produces no harmful effect when exposed to environment.

Lubricants can be classified on the basis of:

1. Physical Appearance

(a)Solid: Film of solid material composed of inorganic or organic compounds like graphite, molybdenum disulphide, cadmium disulphide etc.

(b)Semi solid: Liquid suspended in solid matrix of thickener and additives like Grease.

(c)Liquid: Oils like Petroleum, Vegetable, Animal, synthetic oils etc.

2.Base Oil Resource

(a)Natural Oils Oils derived from animal fats and vegetable oils.

(b)Refined Oils Oils derived from crude / petroleum reserves like paraffinic, napthenic or aromatic oils etc.

(c)Synthetic Oils Oils synthesized as an end product of chemical reactions which are tailored as per needs like Synthetic esters, silicones, polyalphaolefines etc.

3.Applications

(a)Automotive Oils used in automobile and transportation industry like engine oils, transmission fluids,gear box oils,brake and hydraulic fluids etc.

(b)Industrial Oils Oils used for industrial purpose like machine oils, compressor oils. Metalworking fluids and hydraulic oils etc.

(c)Special Oils Oils used for special purpose as per specified operations like process oils,white oils, instrumental oils etc.

3. AUTOMOTIVE INDUSTRY

The automotive industry designs, develops, manufactures, markets, and sells motor vehicles, and is one of the Earth's most important economic sectors by revenue. The first practical automobile with a petrol engine was built by Karl Benz in 1885 in Germany. Benz was granted a patent for his automobile on 29 January 1886, and began the first production of automobiles in 1888. The automotive industry in India is one of the largest in the world and one of the fastest growing globally. Following economic liberalization in India in 1991, the Indian automotive industry has demonstrated sustained growth as a result of increased competitiveness and relaxed restrictions. India's passenger car and commercial vehicle manufacturing industry is the sixth largest in the world, with an annual production of more than 3.9 million units in 2011. The Indian automobile Industry manufactures over 11 million vehicles and exports about 1.5 million each year. The dominant products of the industry are two-wheelers with a market share of over 75% and passenger cars with a market share of about 16%.Commercial vehicles and three-wheelers share about 9% of the market between them. About 91% of the vehicles sold are used by households and only about 9% for commercial purposes. India's automobile industry has raced from a crippling slowdown to scorching growth in less than two years [12,13]. Till twentieth century two-stroke engines penetrated in many sectors like motorcycles, scooters, chainsaws, outboard applications, agricultural machinery, lawnmowers, etc. Usually, two-stroke engines are lubricated by total-loss lubrication method where mixture of oil is either mixed with petrol or is pumped from a separate tank rendering oil being burnt in the combustion chamber[14]. Global demand for the lubricants has been increasing at 2 – 2.5% per annum predominantly in the developing countries due to rapid population growth and rising automotive needs for catering the needs of countries development .In developed countries the growth rate is bit slower at the rate of 1% per annum due to saturation of vehicle population, improved automotive engine technology and enhanced lubricant quality in past few years.The base oil used for the formulation of most lubricants is environmentally hostile mineral oil.Additive packages used as functional agents in the lube oil do add to the growing concern due to the presence of harmful elements.Thus search for environment friendly substitutes to mineral oils as base stock in lubricants has become a frontier area of research in the lubricant industry in the new paradigm of sustainable technology development caused by the alarms of environmental degradations. Formulation of environment friendly lubricants depends primarily on the biodegradability of the base oils and biological additives [15].

4.VEGETABLE OIL - AN ALTERNATIVE

Vegetable oils are chemically triglycerides of fatty acids as shown in fig.2.Triglycerides are the glycerol molecules with three long chain fatty acids generally, attached at hydroxy groups via ester linkage.The fatty acids are often of different lengths and structure .The physical and chemical properties and the behaviour can be attributed to such building blocks.

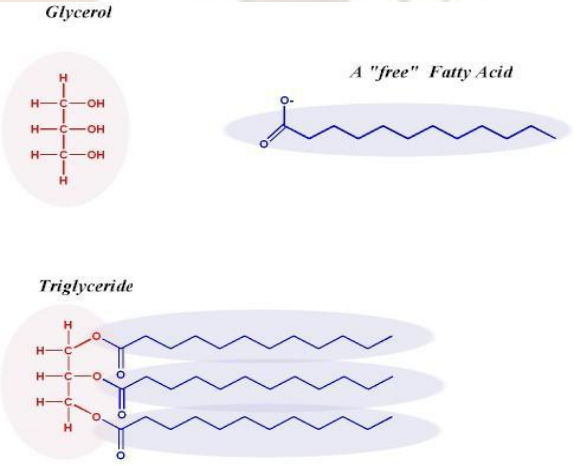

Fig.2 Molecular Structure:Triglycrides of Fatty Acids

Vegetable oils are known to have superior inherent qualities like excellent biodegradability and lubricity, much higher viscosity and viscosity index, enhanced flash and fire points and lower toxicity. Lubricity or oiliness of vegetable oils is attributed to their ability to adsorb to the metallic surfaces and to form a tenacious

monolayer, with the polar head adhering to the metallic surfaces and the hydrocarbon chains orienting in near normal directions to the surface. In general biodegradability means the tendency of a lubricant to be ingested and metabolized by microorganisms. The rate at which lubricants, and other chemicals or additive components biodegrade is related to their chemical structure. Their chemical structure affects their properties, many of which affect performance in the various tests for biodegradability. Recently, environmental behaviour of lubricants such as biodegradability, toxicity,water hazard potential, and emissions has received much attention.

Properties	Mineral Oils	Glycols	Vegetable Oils	Synthetic Esters
Density @ 20 °C (kg/m³)	880	1100	940	930
Viscosity Index	100	100...200	100...200	120...220
Shear Stability	Good	Good	Good	Good
Pour Point, °C	-15	-40...+20	-20...+10	-60...-20
Cold Flow Behavior	Good	Very Good	Poor	Very Good
Miscibility with Mineral Oils	-	Not Miscible	Good	Good
Solubility in Water	Not Miscible	Very Good - Poor	Not Miscible	Not Miscible
Seal Swelling Tendency	Slight	Shrinking	Slight	Moderate
Behavior Against Paint	Good	Poor	Good	Good
Biodegradability (CEC) %	10...30	10...99	70...100	10...100
Oxidation Stability	Good	Good	Moderate	Good
Hydrolytic Stability	Good	-	Poor	Moderate
Sludge Forming Tendency	Good	-	Poor	Moderate
Relative Cost (Mineral Oil =)	1	2...4	2...3	4...20

Table.1 Comparative Analysis of properties of Vegetable Oils

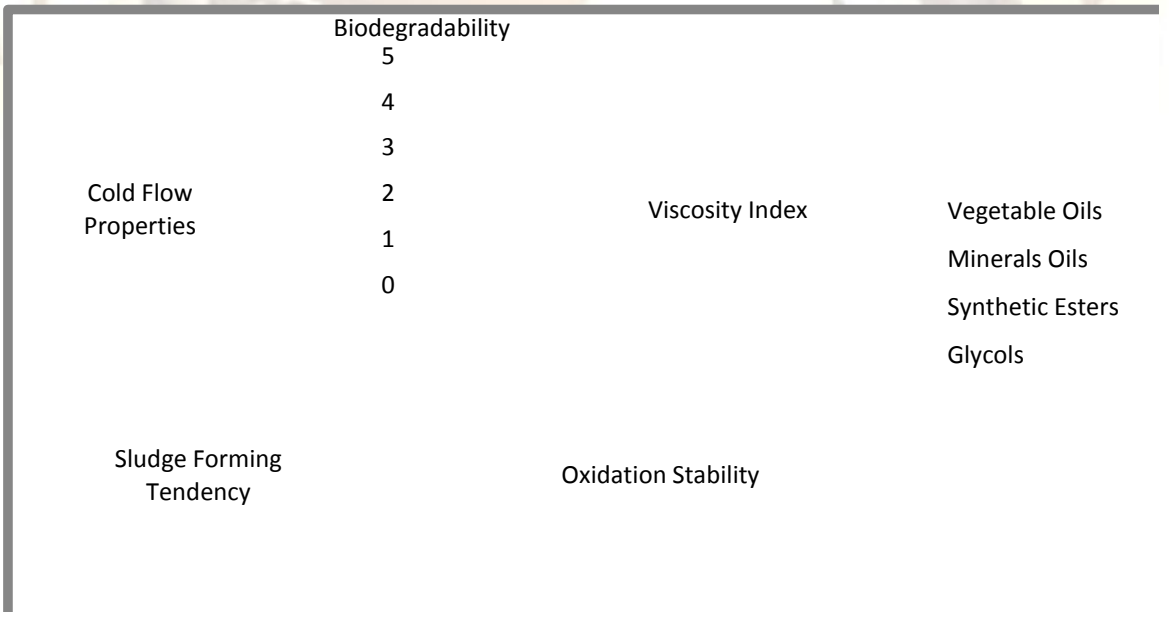

Fig.3 Comparative Index Analysis of Vegetable Oils on Five Point Scale

Table 1 [16]and **Fig. 3** clearly indicates that vegetable oils has potential to be used as an alternative source of lubricants, although they lack in properties like oxidation stability and cold flow properties. These can be improved by utilizing proper additive packages and chemical modification.Vegetable oils are extracted from plants by placing the relevant part of the plant under pressure, to squeeze the oil out. Oils (edible or non edible) may also be extracted from plants by dissolving parts of plants in water or another solvent, and distilling the oil (known as essential oils), or by infusing parts of plants in a base

oil. Vegetable oils can be classified in various ways depending upon the source, applications etc. Oils can be edible or non edible in nature. Globally innumerable amount of such varieties are present.But the need of an hour is to harness proper type that suits the requirement as a lubricant without affecting the ecology and the food requirements. India is the biggest importer of edible oils in the world. Approximately, 16.6 million tones of edible oils consumed each year in India. Consumption of edible oils is increasing at the rate of 5 percent per annum . The edible oil is an important constituent of our daily home edible needs More than 50% of the total consumption of edible oils in India is imported from other countries. Indonesia, Malaysia, Brazil and Argentina are the major exporter of palm oil and soya oil to India. This has pressed hard the country to import substantial amount of edible oils resulting in outflow of Indian currency. Therefore, edible oilseeds usage for fuel and lubricant needs may not be able to meet our domestic requirements for ever increasing population .As an alternative non edible vegetable oil and tree borne seeds can prove to be worthwhile.

S.No.	Non Edible Species	Oil Content %	Seed Estimate 10^6 Tonnes/Year	Oil Yield Tonnes/Ha/Yr
01	Castor	45 – 50	0.25	0.5 – 1.0
02	Jatropha	50 – 60	0.20	2 - 3
03	Karanja	30 - 40	0.06	2 - 4
04	Mahua	35 – 40	0.20	1 - 4
05	Neem	20 - 30	0.10	2 - 3

Table 2 Production and Oil Content Statistics of Non Edible Oil Seeds

Vegetable Oils Edible	Density Kg/m^3	KinematicViscosity $(40^0c),mm^2/s$	OxidationStability $110^0c,h$	CloudPoint ^0c	FlashPoint ^0c
Coconut	807	2.76	35.5	0.0	110
Linseed	892	3.75	0.2	-3.8	178
Olive	895	4.50	3.3	-	-
Soyabean	884	4.04	2.1	1.0	178
Sunflower	880	4.44	0.9	-3.4	183
Palm	876	5.70	4.0	13.0	164
Peanut	883	4.90	2.0	5.0	176
Rapeseed	872	4.44	7.6	-3.3	60
Ricebran	885	4.96	0.4	0.3	-
Vegetable Oils Non Edible	**Density Kg/m^3**	**KinematicViscosity $(40^0c),mm^2/s$**	**OxidationStability $110^0c,h$**	**CloudPoint ^0c**	**FlashPoint ^0c**
Castor	899	15.25	1.1	-13.4	260
Jatropha	880	4.80	2.3	2.7	135
Karanja	920	4.80	6.0	9.0	150
Mahua	850	3.98	-	-	208
Neem	884	5.21	7.1	14.4	42

Table 3 Physio-Chemical Properties of Edible and Non Edible Oils

Table 2. and **Table 3.** [17] Shows production statistics of non edible vegetable oils and the physio chemical properties of comparative vegetable oils that are used as potential lube sources. Species like Simarouba, Neem, Jojoba, Mahua, Wild apricot, Cheura, Kokum, & Tung etc. needs to be evaluated in proper for catering the needs of lubricant formulation. They can be grown and established in marginal and semi-marginal land under varied agro-climatic conditions.Moreover,local yield or variety production should be emphasized rather than the production of non edible vegetable oils on global level which sometimes become difficult due to climatic conditions[18-22].

5. CONCLUSIONS

Non edible vegetable oil based lubricants are renewable and biodegradable in nature and do not interfere with the country's food consumption demands. Environmental compatibility of vegetable oils grants them an upperhand over the conventional mineral oils on account of overall operating costs. Lubricants based on vegetable oils still covers narrow market segment. Although Slowly but steadily due to the concern towards the nature safety and environmental regulations restrictions, lubricants

used in open applications like two stroke engines, chainsaws, forestry etc. which can have direct exposure to soil and water bodies have started to be replaced by such eco-friendly lubricants. The time has come to enforce laws and press policies globally to ensure the safety of our environment when it comes to production, application and disposal of lubricants. Environmental compatibility has to be checked for all cases where there is interference of lubricants taking place in the midst of human and nature. Vegetable oils and predominantly the non edible forms has huge potential in formulation of lubricants boosting the agricultural practices and strengthening the rural economy.

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