Vegetable Oil and Its Derivatives for Lubricants

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The use of vegetable oil for lubrication dated as far back as 1650 BC. Art decorations on the inner wall of the Egyptian tomb of Tehuti-Hetep indicate that olive oil on wooden planks was used to facilitate the sliding of large stones, statues and building materials (Shubkin, 1993). During the second world war, vegetable oils were used for lubrication because there was a shortage of mineral oil. Different railway companies used mineral lubricants compounded with 7%–25% vegetable oil (Odi-Owei, 1988). The oil embargo of 1974 and subsequent escalation of petroleum prices brought a new urgent need for conservation of oil reserves and the development of alternative raw material (Shubkin, 1993). In the 90s, research in vegetable oil lubricants was driven by environmental concerns. The increasing demand for environmentally acceptable lubricant has led researchers to look to vegetable oils as an alternative.

LUBRICANTS

Friction between two rubbing surfaces will cause wear and tear on the engine and machine parts. In the most fundamental sense, a lubricant is a substance that has the ability to reduce friction between two rubbing surfaces. Besides reducing friction, a lubricant also helps to dissipate heat.

Generally the application of lubricant can be divided into two major sections, automotive and industrial. Usually the automotive lubricants would take up about 50%–60% of the market share (*Figure 1*). Automotive lubricants comprise all types of engine oils whereas industrial lubricants are used for various industrial purposes. Examples of industrial lubricants are hydraulic fluid, compressor oil, gear oil, metal working fluid, drilling mud, grease, *etc.*

THE ENVIRONMENTAL CONCERNS OF LUBRICANTS

In general, a lubricant comprises two components, base oil and additives. Usually base oil would take up about 90% of a lubricant and the remaining 10% are additives. For grease, an additional component called a thickener, is used. Normally, the percentage of thickener in a grease formulation is about 10% to 15%. Any accidental spillage of lubricant onto the soil or river could be harmful to the environment because a non-biodegradable lubricant would find its way to the ground

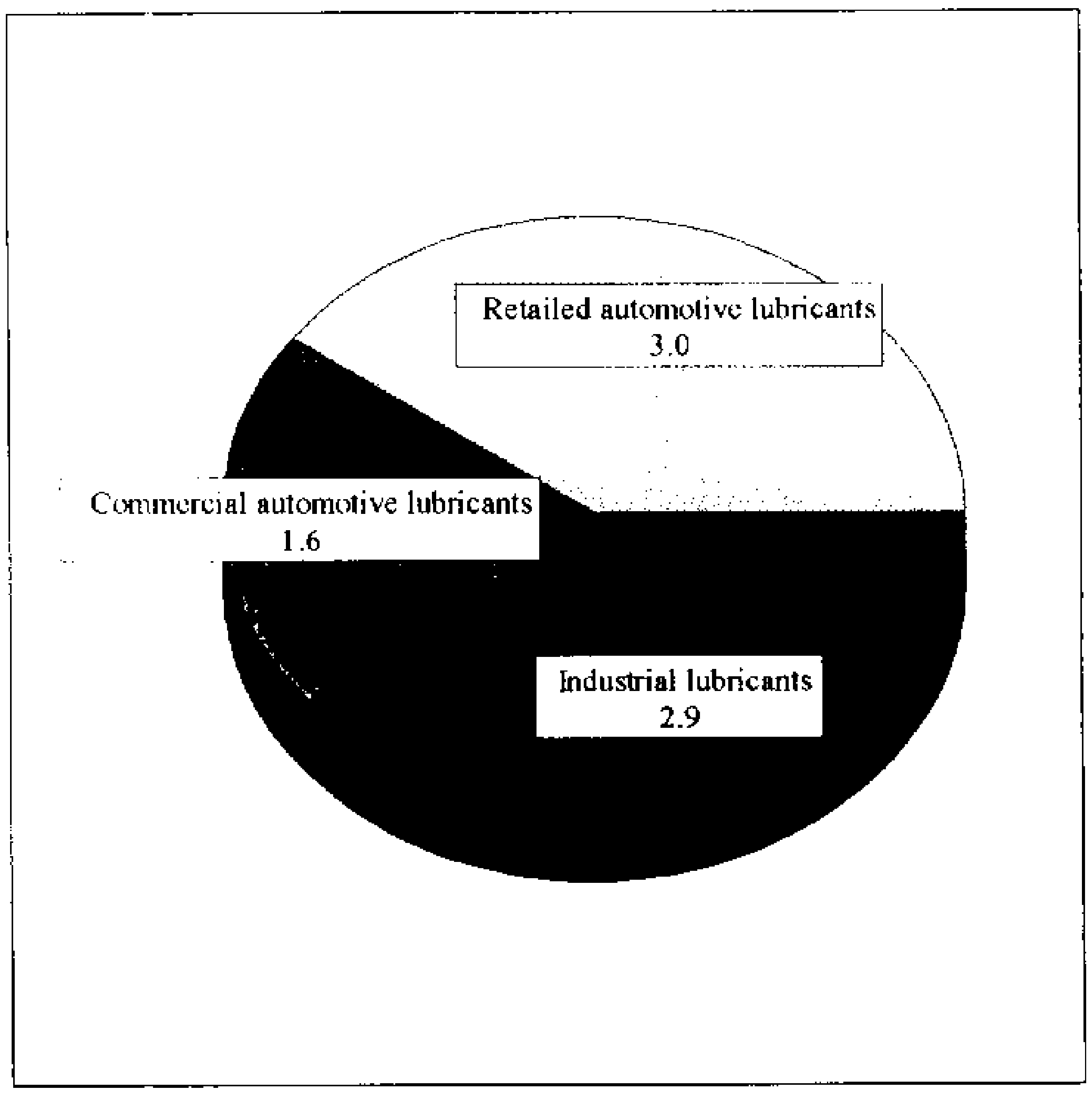

Figure 1. Lubricant sales in U.S. (billion dollars).

and river water. The use of environmentally acceptable lubricant in areas where lubricants may come into close contact with soil and water is therefore greatly encouraged. Examples of these types of lubricants are the two-stroke engine oils, chain saw oil, railroad lubricant, hydraulic oils for construction, mining, tractor, forestry and agricultural equipments and lubricants for snowmobile, ski lifts, *etc*.

In Europe there have been quite a lot of developments on the environmentally acceptable lubricants. The guidelines and legislations for environmentally acceptable lubricants are well spelled out. For example, the Blue Angel Guideline of Germany would require a base stock to be 80% biodegradable and additives to be non-toxic (Hairston, 1994). The Austrian water protection regulation requires the chain saw lubricants to be at least 90% biodegradable, possess low water solubility and contain no halogen or nitrile additives. *Table 1* shows the biodegradability of various base oils by CEC-L-33-A-94 (Kiovsky, 1994).

From *Table 1* we could observe that vegetable oil and synthetic esters show good biodegradability. Since 90% of a lubricant is base oil, therefore the biodegradability of base oils will contribute significantly to the entire biodegradability of a lubricant. Therefore it is logical to use vegetable oil or synthetic esters as base oils for the formulation of biodegradable lubricants.

TABLE 1. BIODEGRADABILITY OF BASE OILS

Mineral oils	30 – 70%
White mineral oil	30%
Polyethers	20 – 70%
Polyethyleneglycol	50 – 80%
Synthetic esters	70 – 95%
Vegetable oil	80 – 99%

VEGETABLE OILS FOR LUBRICANTS

The use of vegetable oils and animal tallow as lubricants is not surprising because they naturally possess good natural lubricity. Some of their common uses prior to 1939 are listed in *Table 2* (Odi-Owei, 1988). Unfortunately they are limited by their poor low temperature fluidity and poor oxidative stability at high temperatures. The most desirable oil for lubricant is an oil with a high percentage of monounsaturated fatty acid, moderate amount of polyunsaturated fatty acid and low amount of saturated fatty acid. The ideal oil has been successfully achieved via genetic modification. Examples are low erucic rapeseed oil or canola oil and high oleic sunflower oil. Their physical properties are depicted in *Table 3*.

TABLE 2. VEGETABLE OILS AND ANIMAL TALLOW AND THEIR USAGE

Vegetable / Animal oil	Common application
Olive oil	Automotive lubricants
Sperm oil	Spindle lubricant in textile mills, automotive transmission fluids, metal cutting fluids, instrument oils
Rapeseed oil	Metal forming processes
Castor oil	Gear lubricants
Coconut oil	Used for compounding gas and petrol engine oils
Palm oil	Used for steel industry for rolling thin gauge strip, railway wagon greases
Tallow	Used for compounding steam cylinder oils

TABLE 3. PHYSICAL PROPERTIES OF VEGETABLE OILS AND MINERAL OIL

Oil	Viscosity at 40°C, cSt	Viscosity at 100°C, cSt	Viscosity index	Pour point, °C	Flash point, °C
100 Neutral mineral oil	20.5	4.1	89	–9	189
Low erucic rapeseed	36.2	8.2	211	–18	346
High oleic sunflower oil	39.9	8.6	206	–12	252
Very high oleic sunflower	40.1	8.6	202	–18	271
Soybean oil	28.9	7.5	246	–9	325

Ref. Naegley, P.C. (1992).

SYNTHETIC ESTERS FOR LUBRICANTS

In many cases, conventional mineral lubricants could not meet the demands of extreme engine performance. One of the typical examples faced by the Germans during the World War II was that tanks, air crafts and other military vehicles could not be started due to the gelation of mineral lubricants in extreme cold temperatures (Shubkin, 1993). This has led to the development of synthetic lubricants. Synthetic lubricants offer better low temperature fluidity, better oxidative and thermal stability, higher flash points, low volatility and less tendencies to form sludge and deposits. There are various types of synthetic base oils. The more common ones are polyalphaolefin (PAO), synthetic esters, polyalkyleneglycol, silicone oil, phosphate esters and polyfluoroalkyl ether. Synthetic ester includes monoesters, diesters, polyol esters, fatty acid esters and complex esters. The raw materials for synthetic esters (*Table 4*) include straight or branched chain fatty acids with 6 to 18 carbons except for dimer acid. These fatty acids can easily be obtained from vegetable oils such as palm, palm kernel, coconut, castor and tall oil and animal tallow. For the alcohol moiety, branched, dihydric and polyhydric alcohol of $C_5 - C_{13}$ could be derived from petrochemical. *Tables 5* and *6* show the typical properties of diester and polyol ester (Kohashi, 1991 and Margeson, 1991).

From *Tables 3, 5* and *6*, it may be observed that diesters and polyol esters have better viscosity indices, lower pour points and higher flash points than mineral oil. These properties are desirable for the formulation of high performance lubricants. For example, diisodecyl adipate and dioctyl sebacate are used for automobile engine oils and Type I aviation turbine oils. The fatty acid esters of neopentyl polyol, pentaerithrityl tetraheptanoate and coco fatty acid of trimethylolpropane esters are applied for automobile engine oils, Type II aviation turbine oils, hydraulic fluids, metal working lubricants and grease (Kohashi, 1991).

CONCLUSIONS

Vegetable oils have the potential to be used for the development of environmentally accepted lubricants due to their good lubricity and biodegradability. Unfortunately they are limited by their poor low temperature fluidity and oxidative stability. These limitations could be overcome by selecting the carefully genetically engineered oils and lubricant additives. Synthetic esters on the other hand have more desirable

TABLE 4. ESTER RAW MATERIALS

Alcohol	Carbons	Source	Acids	Carbons	Source
2-Ethylhexyl alcohol	8	Petroleum	Adipic	6	Petroleum
Isooctyl alcohol	8	Petroleum	Azelaic	9	Tallow, Tall, Palm
Isodecyl alcohol	10	Petroleum	Sebacic	10	Castor
Isotridecyl alcohol	13	Petroleum	Dimer	36	Tallow, Tall, Palm
Pentaerythritol	5	Petroleum	Phthalic anhydride	8	Petroleum
NPG	5	Petroleum	Valeric	5	Petroleum
TMP	6	Petroleum	Hexanoic	6	Coconut, Palm kernel
			Heptanoic	7	Petroleum
			Octanoic	8	Coconut, Palm kernel
			Pelargonic	9	Petroleum, Tallow
			Decanoic	10	Coconut, Palm kernel
			Pelargonic	9	Petroleum, Tallow
			Lauric	12	Coconut
			Myristic	14	Coconut, Palm kernel
			Palmitic	16	Tallow, Coconut, Palm, Palm kernel
			Isostearic	18	Tallow, tall
			Oleic	18:1	Tallow, Palm
			Mixed	6-8-10	Coconut, Palm kernel

NPG = neopentyl glycol
TMP = trimethylolpropane

TABLE 5. TYPICAL PROPERTIES OF DIESTER

Diester	Viscosity at 40°C, cSt	Viscosity at 100°C, cSt	Viscosity index	Pour point, °C	Flash point, °C
Diisooctyl azelate	12.2	3.3	140	–65	218
Di-2-ethylhexyl azelate	10.3	2.9	138	–70	232
Diisodecyl azelate	17.5	4.3	161	–70	32
Ditridecyl azelate	33.8	6.4	145	–55	243
Diisodecyl adipate	13.7	3.5	144	–70	224
Ditridecyl adipate	26.7	5.3	135	–50	235

TABLE 6. TYPICAL PROPERTIES OF POLYOL ESTERS

Polyol ester	Viscosity at 40°C, cSt	Viscosity at 100°C, cSt	Viscosity index	Pour point, °C	Flash point, °C
Neopentyl glycol, C_9 Acid	9.3	2.6	132	–34	210
Trimethylolpropane, $C_5 - C_{10}$ Acid	19.6	4.2	131	–68	249
Trimethylolpropane, C_9 Acid	22.9	4.8	143	–57	254
Trimethylolpropane, $C_{18:1}$ Acid	49.4	9.3	187	–46	321
Pentaerythritol, $C_5 - C_{10}$ Acid	25.0	5.0	138	–62	257
Pentaerythritol, C_9 Acid	35.1	6.3	145	–18	288

properties because they can be tailor made by careful selection of fatty acids and alcohols to give the desired properties. Most of the raw materials could be derived from vegetable oils such as palm oil, palm kernel oil and coconut oil. A major limitation however is their cost. ■

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