PALM OIL USAGE IN LUBRICANTS

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POINTS OF DISCUSSION

- **Introduction**
- **Issues in the lubrication markets.**
- **Performance test review.**
- **Desired vegetable oil characteristics and properties.**
- **How do we make palm oil work?**
- **Addressable markets**
- **Realistic markets**
- **Conclusions**

ABSTRACT

Due to growing environmental concerns, vegetable oils are finding their way into lubricants for industrial and transportation applications. These oils indeed offer significant environmental benefits with respect to resource renewability, biodegradability, as well as providing satisfactory performance in a wide array of applications. Synthetic ester based fluids may also offer these advantages, but their cost can be prohibitively high. Formulating with vegetable oils, especially the highly saturated oils, however present unique challenges. These are the low temperature viscosities, oxidative, and hydrolytic instabilities problems associated with the triglyceride. Palm oil along with some other common and commercially available vegetable oils will be reviewed as to their applicability and define those issues that may find these oils unsuitable or restricted to some limited applications.

INTRODUCTION

Continued growing environmental concerns are providing the impetus for increased demand and usage of vegetable oil utilization in lubricants for many applications. Of the 5-10 million tons of petroleum based oleochemicals entering the biosphere every year, about 40% comes from spills, industrial and municipal waste, urban runoff, refinery processes, and condensation from marine engine exhaust. Oleochemical pollutants are derived from the food industry, petroleum products, and by products such as lubricating hydraulic and cutting oils. Vegetable oil can offer significant environmental advantages with respect to:

- ✓ resource renewability
- ✓ biodegradability,
- ✓ adequate performance in a variety of applications.

Synthetic esters based fluids also offer these advantages, but their cost is prohibitive for many markets. Formulating with vegetable oils present many challenges is tailoring specific products for lubrication. The notable challenges are:

- ✓ oxidative stability
- ✓ hydrolytic stabilities
- ✓ low temperature properties that are innate characteristics of the triglyceride molecule.

Olive oil was used as a lubricant as long ago as 1650 BC. Various oils obtained from olive, rapeseed, castor beans, palm oil and the fats from sperm whale, animal lard, and wool grease were used from the time of 50 AD until the early 19th century. These natural oils had limited stability., The Industrial revolution of the late 18th century and its expansion into the 19th century stimulated the need for inexpensive, thermally and oxidative stable lubricants. Serious efforts were initiated in the 1930s to develop synthetic lubricants for operation over wide temperature ranges. These synthetic hydrocarbons, organic esters and others. Today, vegetable oils are drawing attention as biodegradable alternates for synthetic esters because they are less expensive and are available from renewable sources.

Currently, over 100 MM MTs of vegetable oils are produced worldwide. This doubling every 20-25 years and will surpass 175 MM MTs by 2020. Of this,16 million MTs tons are produced in the United States.

In this presentation, I will focus on the use of palm oil and competitive whole vegetable oils and not esters or other structured molecules from various processes used in the oleochemical industry. Comparison of potential commercially available vegetable oils as their potential utility in lubrication applications will be reviewed. The costs of these “new oils” are usually much lower than synthetic esters and therefore provide more potential for the successful utilization of these products in lubrication base fluids.

Historically speaking, recent vegetable oils have been used in applications where leakage of equipment is inevitable, or where a system is designed to function by loss lubrications. They are………….

- ✓ Two stroke engine oil
- ✓ Chain saw oils
- ✓ Hydraulic oils
- ✓ Mold release oils
- ✓ Farming, mining, and forestry equipment
- ✓ Open gear lubricants
- ✓ Greases
- ✓ Fuels

Lubricants can be classified into two general categories as engine and non-engine. The two categories are:

<u>Engine Lubricants</u>	**<u>None-engine</u>**
Gasoline engine oils	Transmission fluid
Diesel engine oils	Power steering fluids
Automotive diesel oils	shock absorber fluids
Stationery diesel oils	Gear oils
Railroad diesel oils	Hydraulic fluids
Marine diesel oils	Tractor fluids
Natural gas engine oils	Industrial
Aviation engine oils	Metalworking fluids
Two-stroke engine oils	Greases

It is estimated that around 60 thousand metric tons of vegetable oils are currently used in the United States. Synthetic esters and other non-mineral oil base fluids are currently available and being used in lubricants designated for agricultural, forestry, food processing, mining, construction, and recreation equipment.

Specific market applications are:

- ✓ Two-stroke oils
- ✓ Chain Bar oils
- ✓ Hydraulic fluids
- ✓ Cutting oils
- ✓ Concrete mould release agents
- ✓ Transformer oils
- ✓ Refrigeration oils
- ✓ Farm tractor oils

ISSUES IN LUBRICATION MARKET

Besides the performance issues of vegetable oils utilization versus mineral oil based systems, relative cost of the base fluids is always of concern. It is believed that the approximate relative costs of the various base fluids are:

✓	Refined mineral oils -	1
✓	Vegetable oils -	1.5 - 2
✓	Synthetic esters -	4 - 12

The advantages of vegetable oils as base fluids in lubricants are perceived to be the following:

- ✓ Non-toxicity
- ✓ Biodegradability
- ✓ Resource renewable
- ✓ Affordable application cost
- ✓ Good lubricity
- ✓ High viscosity index

One of the key needed oil property or characteristics that vegetable oils lack in general are the following:

- ✓ Oxidative instability
- ✓ Poor low temperature properties
- ✓ Perceived poor hydrolytic stability

Fluidity of oil is mainly determined by the efficiency of molecular packing, intermolecular interactions, and molecular weight. Saturates have too high a level of crystalline symmetry, which facilitates interlocking of the sharp needle-like triacyglyercol crystals as temperature decreases. Vegetable oils and their double bonds influence low temperature behavior. The FAC of most of the vegetable oils that are readily available and inexpensive are not suitable for lubrication due their high saturates or polyunsaturates fatty acid content. Monounsaturated fatty acid oil present optimum oxidative stability and lower temperature properties. As a consequence, vegetable oils that have high stability and low pour points can be produced by converting all the fatty acids into a monounsaturated fatty acid. Thus, base fluids for lubricants must have a balance of fatty acids, preferably a high level of monounsaturated, minimal polyunsaturates, and ideally no saturarates at all for cold climates.

The following data below gives an example of the aforementioned properties of vegetable oils as compared to mineral oils. Unlike most mineral oils, vegetable oils display very high viscosity indices (VI). This is a relative measurement in change of base fluid viscosity between 40°C and 100°C and indicates the change in viscosity over an extended temperature range. Vegetable oils afford higher flash points as compared to mineral oils. In terms of pour point, vegetable oils are comparable to mineral oils except for one point. Mineral oils are more responsive to pour point depressants additives and give pour points of -30°C to -50°C. Vegetable oils are not as responsive to conventional pour point depressants since the conventional pour point depressant have been developed for the paraffin waxes found in mineral oils versus the traditional waxes found in most vegetable oils.

Oil	**Viscosity 40°C cSt**	**Viscosity 100°C cSt**	**Viscosity Index**	**Pour Point °C**	**Flash Point °C**
Coconut oil	27.7	6.1	175		
350 Neutral mineral oil	65.6	8.4	97	-18	252
Low erucic rapeseed oil	36.2	8.2	211	-18	346
High oleic sunflower oil	39..9	8.6	206	-12	252
Conventional soya oil	28..9	7.6	246	-9	325
Palm oil	39.7	8.2	188	**?**	**?**

However, one should not need to worry about the shortcomings of vegetable oils for lubrication. Mineral oil fluids, like vegetable oils, cannot meet most lubrication performance needs without additives. Available additives that enhance base fluids are:

- ✓ Antioxidants
- ✓ Detergents
- ✓ Dispersants
- ✓ Viscosity Modifiers
- ✓ Pour Point depressant
- ✓ Antiwear agents
- ✓ Rust and corrosion inhibitors
- ✓ Demulsifiers
- ✓ Foam inhibitors
- ✓ Thickeners
- ✓ Friction Modifiers
- ✓ Other additive e.g., dyes, biocides, etc.

Additives are found in almost any lubricant system tailored to enhance key performance attributes. The following table shows which applications the additives and % is:

Auto engine oils	47%
Industrial engine oils	16%
Other industrial oils	21%
Gear oils	2%
Metal working	2%
Greases	1%

The fatty acid composition of vegetable-based oils determines, to a large extent, their lubricating performance. The fatty acid composition is determined largely by the ratio and position of carbon-to-carbon double bonds. The following table shows the qualitative effect of fatty acid profile upon performance properties of base fluids for lubricants:

Qualitative effects of fatty acid profile upon performance properties of base fluids for lubrications.

Physical Properties	**Saturates - 1**	**Saturates - 2**	**Mono - LC**	**Polys - LC**
Oil	**Coconut**	**Palm**	**HO rapeseed**	**Soybean**
Main fatty acid	50% C12:0	45% C16:0	80% C18:0	75% C18:2&18:3
Oxidative Stability	Excellent	Excellent	Very good	Very Poor
Low Temp Properties	Poor	Poor	Good	Good
Hydrolytic stability	Moderate	Moderate	Good	Good

PERFORMANCE TESTS REVIEW

Unlike the use of vegetable oils in the food industry, the lubrication industry has its own testing protocols for products, and the following are some of the tests are carried out to evaluate the performance and effectiveness of a formulation or key component.

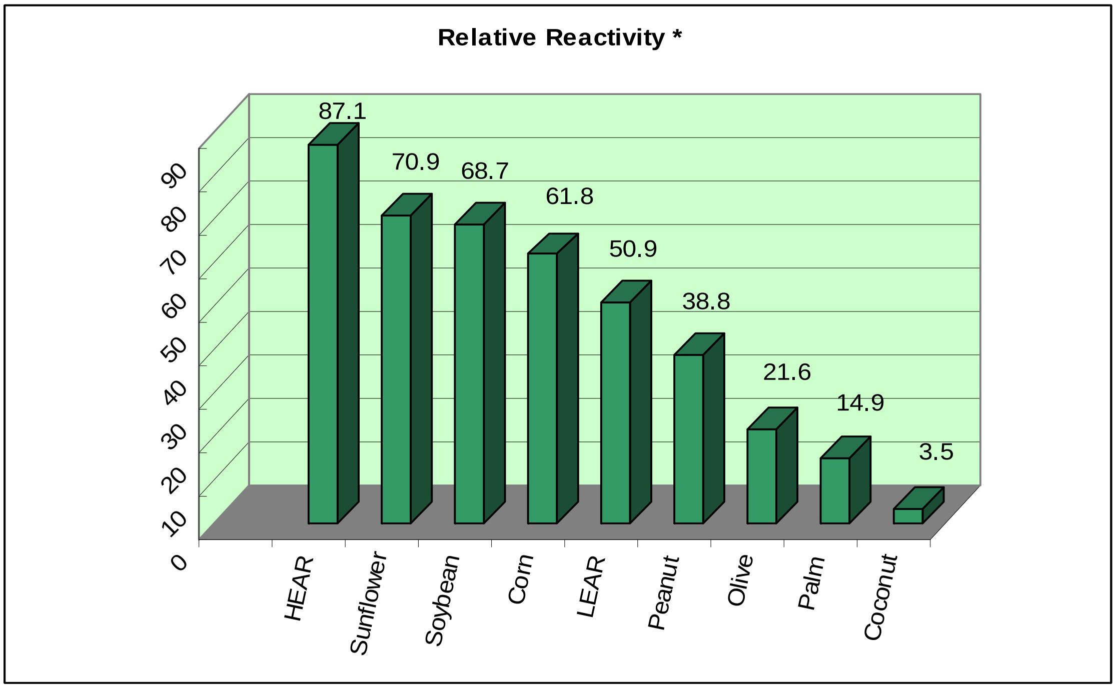
- ✓ Pour Point (ASTM D 97)
- ✓ Brookfield Viscosity (ASTM D2983)
- ✓ Oxidative Stability
- ✓ Industrial Gear Oil High Temperature Test (ASTM D2893)
- ✓ Turbine Oil Oxidation Test (ASTM D943)
- ✓ Hydrolytic Stability (D2619)
- ✓ Corrosion Testing (D665&D130)
- ✓ Rotary Bomb Oxidation (RBOT) ASTM D2272

- ✓ **Pour Point (ASTM D 97):** The pour point of a formulation is the temperature below which it stops flowing. For most low temperature performance requirements, pour point depressants are used. They are not as effective in vegetable oils.

- ✓ **Brookfield Viscosity (ASTM D2983):** The technique is used to determine the low temperature viscosity of lubricants such as automotive gear oils, tractor fluids, etc. Normally high oleic oils show poor Brookfield viscosity, but this behavior can be helped with the addition of pour point depressants.

- ✓ **Oxidative Stability:** Because vegetable oils are unsaturated, they tend to be less oxidatively stable then mineral oils. Small amounts of antioxidants (0.1-0.2%) are effective for mineral oil formulations. For vegetable oils, larger dosages are required (1-5%) to inhibit oxidative destruction. A number of screen tests are used in the lubrication industry to evaluate oxidative stability of lubricant formulations.

<u>Approximate Relative Rates of Oxidation of Vegetable Oils</u>



' Sum of decimal fractions of fatty acid types multiplied by relative rate of oxidation for that type

Consequences:

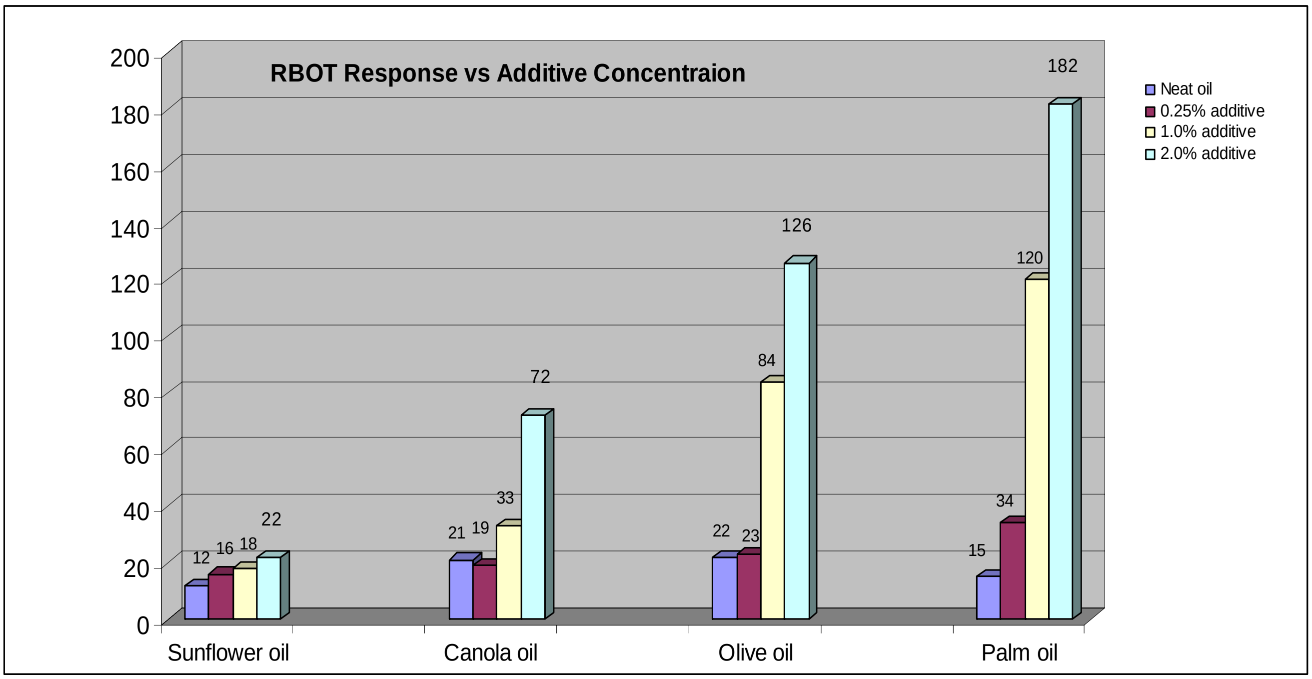
If vegetable oil oxidation follows the same mechanistic path as mineral oil, then the same types of stabilizers should work:

- ✓ Radical scavengers
- ✓ Hydroperoxide decomposers
- ✓ Metal passivators

If vegetable oils react with oxygen quicker than mineral oils, then larger treat levels of stabilizers will be needed.

✓ **Rotary Bomb Oxidation (RBOT) ASTM D2272:** With certain high oleic vegetable oils and certain antioxidants, RBOT's comparable to combination of mineral oils ands antioxidants are achievable. Oxidation tests we are familiar are the AOM and OSI test procedures. There are many examples and data supporting this property.

The following chart shows RBOT values of some vegetable oils, neat, and with additive to increase stability. Note: Minutes to 25-lb. oil pressure loss.



- ✓ **Hydrolytic Stability (D2619):** Exposure to moisture of lubricant during use is expected and must be measured since hydrolytic stability is a factor and consistent lubricating properties are maintained. It depends upon the catalytic effect of copper at elevated temperatures in the presence of water to accelerate the rate of hydrolysis. Hydrolytic stability further tends to correlate with hydrophobicity. Fatty acids with chain length in the range of 12 - 14 carbon atoms are usually hydrolytically stable, whereas medium chain triglycerides in the chain length of 2 - 11 carbon atoms are not so stable.

- ✓ **Biodegradability:** Most vegetable oils and synthetic esters are inherently biodegradable. For certain applications, environmentally acceptable lubricants should be readily biodegradable. Several tests have been developed to measure biodegradability. The CEC L-33-T-82 and the modified STURM test are the two of the most widely used tests to measure biodegradability. Vegetable oil systems give the best biodegradability for all lubricant base fluids. Biodegradation can be defined as follows. “Primary” degradation is defined as degradation to the minimum extent to change the identity (chemical and physical properties) of the substance. “Ultimate” biodegradation is when the substance is totally converted by micro-organisms into carbon dioxide, water, mineral salts, and biotic mass. Also known as mineralization., The following chart summarizes the common tests and % biodegrability for base fluids:

Biodegradable Fluids

Examples:

Product	CEC L-33-A-93 (21days)	Modified Sturm. (28 days)
Mineral oil	15% - 75%	5- 50%
Synthetic esters	> 55%	> 40%
Vegetable oils	> 90%	> 70%
“Readily Biodegradable”	67% - 80%	> 60%”

Application Testing

Typically, a formulation is subjected to a number of screen tests, as just mentioned, to evaluate its efficacy in a particular application. Once a formulation passes most or all the screen tests, it is tested in the actual end use equipment. At the end of the test, drains and parts are rated for sludge formation, acid build-up, deterioration in the formulation, wear, scuffing, weight loss, etc. Each application has its own set of specific tests and adheres to them very closely. For example, the test data for a hydraulic fluid requires the following:

- ✓ RBOT (ASTM D2272)
- ✓ Kinematic Viscosity
- ✓ Cincinnati Milacron - Cu rod/Fe rod/sludge
- ✓ Hydrolytic Stability
- ✓ Oxidation ASTM D943, hours
- ✓ Storage Stability
- ✓ Foam (ASTM D892)
- ✓ Rust ASTM D665
- ✓ Demulsibility (ASTM D1401)
- ✓ 4-Ball wear
- ✓ Copper strip
- ✓ Pour Point
- ✓ Brookfield Viscosity

Other types of lubricants, as I indicated below, have particular tests that have been developed with OEMs toward a particular function. However, many of the same tests, both in screening, and application are similar, if not the same. If needed, the tests specific to each end-use are well known and available upon request. They are very detailed to elaborate upon and do not serve any useful purpose within the scope of this presentation.

DESIRED VEGETABLE OIL CHARACTERISTICS

The lubricant industry could be poised to take advantage of oilseed biotechnology to produce high performance base oils that are compatible with the current stable of additives used in the lubrication industry. The drivers that will influence the vegetable base oil composition and market penetration are:

- ✓ Regulatory initiatives
- ✓ Public perception of need
- ✓ OEM acceptance and continued support
- ✓ Cost/benefits

The world market for environmentally friendly lubricants, those based on synthetic esters and vegetable oils, is forecasted to grow to over 100 millions tons in the years 2002-2005. The majority of demand will be in Europe and Canada, where environmental awareness and regulations are highest.

Selection of vegetable oils for this industry will heavily rely on relatively low cost, acceptable low temperature properties, and acceptable oxidative and thermal stability. Compatibility of certain additives for particular applications will be essential to complete the product package. Vegetable oils with iodine values (IV) between 50 and 130 are ideal for hydraulic fluids. Below 50, fluids have high pour points due to lack of unsaturation, and above 130, oils tend to be oxidatively unstable. Fatty acids contained in some vegetable oils are polar in nature and tend to cling to metal surfaces more effectively than mineral oils and therefore provide improved lubricity.

As mentioned earlier in this paper, the use of additives in formulated lubricant systems will undoubtedly will be needed. This is even true for mineral oil based products that have successfully used for decades. Requirements for high performance compatible vegetable oils are:

- ✓ High biodegradability; Low toxicity
- ✓ Excellent Oxidative Stability
- ✓ Good low temperature properties
- ✓ Lower cost than synthetic esters
- ✓ Performance comparable to mineral and synthetic esters

Accepting the fact and notion, that additives can compensate for the many inadequacies of vegetable oils, it is therefore to utilize a vegetable oil can provides the rudimentary basic properties. Maximum oxidative stability while maintaining fluidity. The ideal vegetable oil, regardless of source, e.g., palm, soya, sunflower, etc., would not need to have an oleic content over 90%. It has been shown that after the saturates have been reduced to low levels, such as 2% max or less, that oxidative stability suffer since saturates provide stability in the composition. Since additives to finished lubrication products is always essential, the focus should be at having the lowest cost vegetable oil having the “ideal” fatty acid composition.

Some suggestions and recommendations follow. First, the following are examples of currently available lubrication oriented based vegetable oil to the industry.

Some guidelines for properties of a vegetable oil designed for lubrication base oils are:

Viscosity, cSt @ 40°C	35-30
Viscosity Index, VI	greater than 200
Iodine Value	94-126
Saponification Number	186-198
Specific Gravity	0.91-0.92
Pour Point, °C	-20
Flash Point, °C	259

Co solvents, such as synthetic esters, are often employed to attain the desired pour point specification for many low temperature demanding lubricant systems.

Some vegetable oils inherently contain natural occurring antioxidants can also assist in oxidative stability properties. Although most oils go through a deodorization process, b usually the final step in the vegetable oil refining process, natural occurring antioxidants do carry through into the finished products.

Wax content in some vegetable oils varies and could have an impact on the performance of base oil for lubrication. Normally these waxes are taken out by a winterization and filtration processes, these components can either improve or reduce the performance of the lubricant, depending on the use and application.

To summarize the value and utility of vegetable oils as base fluids for lubrication, the advantages & disadvantages are listed below:

Advantages (+)

Very high viscosity indexes
Good thermal stability
Low volatility
High flash points
Good miscibility with other lubricant base fluids and solvents
Good additive compatibility

(+ / -)	Polar nature of the ester linkage in vegetable oils imparts good lubricity, but also competes with the surface active additives.

Disadvantages (-)

- Poor oxidative stability
- Questionable hydrolytic stability
- Poor low temperature characteristics
- Poor response to pour point depressants

How do we make palm oil work in lubricants?

Having defined the oil characteristics required for a "suitable" vegetable oil base fluid, can palm oil be indeed used? Let's look at some possible solutions of improving low temperature viscosity and pour points.

- ✓ Fractionated palm oil: Various palm olein fractions are available in the marketplace that is somewhat liquid at room temperatures. This includes the "super olein" fractions that are appearing now in the market place.

	Palm oil	Olein A	Olein B	Olein C	Olein D
% FAC					
C12:0	0.1-0.4	0.41	0.16	0.3	0.4
C16:0	40.9-47.5	40.8	38.7	34.7	31.5
C18:0	3.8-4.8	4.2	4.4	3.7	3.2
C18:1	36.4-41.2	40.7	42.5	46.1	49.6
C18:2	9.2-11.6	11.58	12.1	13.1	13.7
IV	50.1-54.1			62.9	66.4
CMP, ° F	103.5		53.5		
Cloud Pt, °C				5	
% SFI @					
50° F	47 - 56	2.5	1.6	2.5	1.4
70° F	20 - 27	0.7	0	0	0

- ✓ Interesterification with other potential vegetable oils such as high oleic canola oil.

- ✓ Blending with synthetic esters to improve low temperature properties such trimethylol propane trioleate (TMP) or trimethylolethane tetraoleate.

- ✓ Transesterfication with various polyols

- ✓ Genetic engineering of palm to reduce saturates and increase monounsaturates

The aforementioned process technologies will in fact improve palm oil properties, but will have an inverse effect on the final costs of the lubricant systems. In fact, many of these potential solutions are not realistic for the lubricant industry

ADDRESSABLE MARKETS

It was previously mentioned that lubricants can be divided into two major categories. Engine lubricants and non-engine lubricants. The engine lubricant systems are probably the most challenging and demanding for performance traits. In many of the engine applications, vegetable oil systems will never meet the technical and performance demands. The most promising area in engine oils is the two-cycle and 4-cycle engine oils. The none-engine lubricants have lesser technical and performance demands in lubrication properties and therefore represent the best potential opportunities for vegetable oil based fluids. The key applications are:

- ✓ Two -cycle engine base oils
- ✓ Antiwear hydraulic fluids
- ✓ Chain Bar lubricants
- ✓ Gear oils
- ✓ Metalworking fluids
- ✓ Food machinery lubricants
- ✓ Textile lubricants
- ✓ Grease base fluids

The key factors for vegetable oil based lubricant marketing success are: (Order of Priority)

- ✓ Technical Quality
- ✓ Performance
- ✓ Price
- ✓ Safety in use

The most promising areas will now be reviewed in terms of market size and specific issues facing each application area.

Two Cycle Engine Oils

Two-cycle engines by design emit part of their fuel and lubricant unburned. Outboard motors are particularly problematic due to direct discharge into the water and use of vegetable oil based lubricants is already mandated in parts of the world such as Europe. Vegetable oil based systems could offer high performance and considerable savings over ester based lubricants.

Potential customers: Major oil companies: Castrol, Texaco, Mobil, Fina, BP
Independent lubricant manufacturers: Lubricating Specialties

Addressable Market Size: 50-70 Thousand Metric Tons

Issues: Cost issues will always remain and market growth will accelerate when governmental legislation are enacted. The vegetable base oil needs to have good low-temperature properties, good oxidative stability, and good miscibility with gasoline.

Vegetable Oil Based Hydraulic Fluids

Antiwear hydraulic fluids represent the largest market segment growth for vegetable oils. The immediate markets are in Canada and Europe, with the US market to trail development and usage of these type of systems. Key aspect for growth in this area is to demonstrate higher performance and value as compared to other commodity oils. Manufacturers want product differentiation with performance demands getting higher. The threat of regulation is always hovering with spills and waste disposal. For this application, benefits and concerns are summarized as:

Benefits

- Good biodegrability and low toxicity
- Anti-wear properties
- Protection against rust and copper corrosion
- Good filterability
- Pour point approximately -20° F
- Compatible with conventional hydraulic seals
- Miscible with mineral oils and synthetic esters

Concerns

- Pour thermal/oxidative stabilities

Potential Customers: Major oil companies such as Mobil, Texaco, and Castrol
Independent manufacturers such as EF Houghton, Citgo

Addressable Market Size: 350 thousand metric tons with realistic short-term of 10 thousand. for vegetable oil based fluids.

Issues: Need to partner with someone among the major oil companies who manufactures and distributes the hydraulic fluid.

Gear Oil Lubes

The driving forces for vegetable oil use are because it is considered as a “loss” lubricant and a threat to environmentally sensitive areas. The market trend is toward segmentation to higher and lower quality segmentation. Largest potential for vegetable oil base fluids are:

- ✓ Mining
- ✓ Agricultural
- ✓ Outboard Engine and marine applications
- ✓ Food Machinery

Addressable Market Size: 50 Thousand Metric Tons (Open gear)
40 Thousand Metric Tons (Closed gear)

Metalworking Fluids

High stability liquid vegetable oils appear to be well suited for applications where neat oils used and varnish is problematic, such as aluminum casting and rolling. The high stability of these type of oils, coupled with low toxicity, makes them attractive for use in areas where worker exposure to mineral oil mists through breathing or skin contact is a problem. The US metalworking plants are under pressure from the government on their waste water discharge and from the worker's union on worker exposure

Addressable Market Size: 540 Thousand Metric Tons

Textile Lubricants

High temperature stability and lubricity are key performance characteristics for textile lubricants. Esters of oleic, erucic, and coconut fatty acids are used in various aspects of fiber processing. Textile lubricant formulators predict that knitting lubricants which are currently mineral oil based may convert to vegetable oil or esters. Similar to other lubrication areas, both environmental concerns and health issues regarding mineral oil based lubricants in fiber and textile production will encourage and accelerate the conversion to vegetable oil based lubricating systems for this market.

Addressable Market Potential: 45 Thousand Metric Tons

Potential Customers: Lubricant suppliers - Goulston, Cognis, Hoechst, High Point
Fiber producers - Monsanto, Dupont, Allied, Milliken

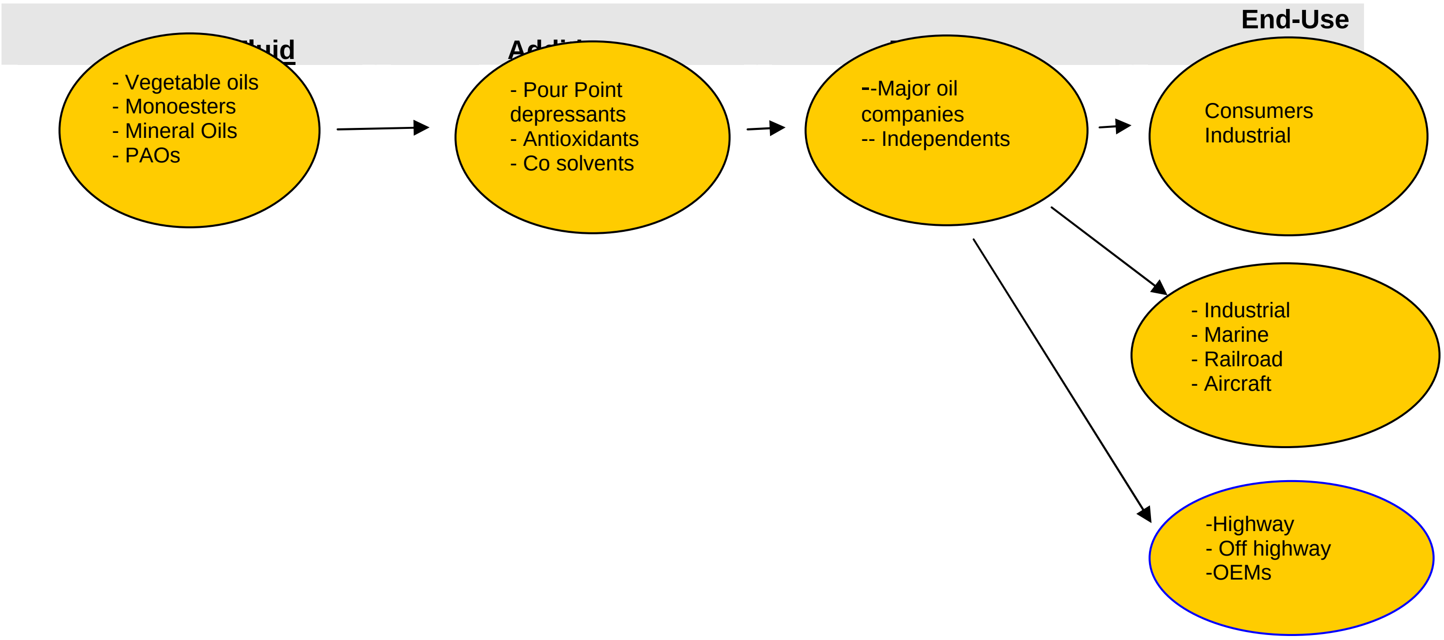
Grease Base Fluids

This is a specification driven market where manufacturers want more packages, less components, and product differentiation. Environmental driving forces are not strong, but could be a significant selling point if performance level are maintained with vegetable oil products. Highest needs or fits in mining, agriculture, and railroad. Best price/performance vegetable oil will win out!

Addressable Market Potential: One million metric tons.

Potential Customers: Major oil companies- Texaco, Castrol, Mobil, Fina
Independents: Cato, Lubricating Specialties

The following diagram depicts the path for compounding and marketing a lubricant system to the various market segments.



Realistic industrial applications for palm oils

Food Machinery Lubes

Food processing is a $500 billion industry in the United States.

$2.8 billion of this amount is food production machinery used to support this business

All the equipment, conveyors, mixers, canners, cappers, have a steady appetite for lubricants well over $700 million worth a year. Types of lubricants permitted:

- ✓ H1: For incidental contact that could occur. Only certain base stocks and additive concentrations are allowed and restricted to certain levels.

- ✓ H2: Lubes and greases, a less restrictive category, used only when no food contact is possible.

- ✓ H3: Products made of edible oils, used as release agents, rust preventatives on surfaces such as hooks and trolleys. These categories were one controlled by the USDA and ended when NSF International stepped in as a third-party certifier. Each manufacturer certifies that its products are made in accordance with USDA and FDA requirements, and its formulations are reviewed by NSF for compliance.

For example, H1 type systems may be:

- ✓ Technical white oils
- ✓ Polyalphaolefins
- ✓ Certain silicone fluids
- ✓ Esters
- ✓ Edible vegetable oil – may have performance limitations and be too pricy.

Palm oil and palm olein are highly suitable:

- ✓ Good adhesion to metal surfaces
- ✓ High affinity for metal and palm oil with 33° C-36° C melt point can be easily applied
- ✓ Resistance to oxidation
- ✓ High melting points

Chain Bar Lubricants

This market application segment requires very little technology and basically needs any oil with an added tackifier for the oil to stay on the bar of the chain saw. It is a currently established market and based on cost. There is minimal cost to be in this market and will probably have future legislation for its use. Must be able to differentiate your product or oil from the competitive field.

- ✓ No industry specs
- ✓ Each company sets its own standards
- ✓ Areas of importance:
  - Viscosity @ 40° C, 100° C
  - Viscosity index
  - Pour point
  - Flash point
  - Tackiness

Addressable Market Size: 45 Thousand metric tons

Issue: Cost competitive market!

Textile Lube Oils

Certain vegetable oils are used in textile and fiber manufacture to lubricate fibers and make them tolerate processes such as spinning and weaving operations. Vegetable oils are superior to mineral oils in that they do not mist like mineral oils, are biodegradable, and have performance properties equal to mineral oils. Palm oleins are well suited for these applications

Metal working

Steel and aluminum foundries use lubricants that are designed to:

- ✓ Tolerate high temperature
- ✓ Withstand severe vibration and shock
- ✓ Undergo consistently high loads

Rolling mills, furnaces, and foundries are hostile environments and need to be treated with respect. Lubricants use must also meet the highest safety standards, as well as being non-toxic and environmentally friendly.

Hot and cold rolling oils, cutting oils, particularly for aluminum industry for hot rolling. Good stability and excellent pressure performance.

For steel industry, residue from oil after burn off remaining on surface provides a shiny and brighter surface.

Conclusions

As you have seen from this presentation, very little information exists on the performance or suitability of palm oils in lubrication. Many formulators in the past have ruled out palm oil due to viscosity and low temperature properties. Although the overall global picture for lubricants is glum due to mature markets, low volume growth, declining demand in certain regions, there is an overall opportunity in terms of qualitative growth, i.e., innovation of products, services, and systems.

Criteria that would encourage increased of vegetable oil based lubricants that could include **palm oil** are as follows:

- ✓ Prices equal to conventional products
- ✓ New legislation
- ✓ Technical performance equals conventional products
- ✓ More product information from suppliers
- ✓ Recommendation from OEM
- ✓ Prices lower than conventional products
- ✓ Technical performance better than conventional products

This certainly includes novel and unique vegetable oils being developed now and in the future, including palm oil based systems. Although very little work has been done with palm oil, including the olein fractions, genetically engineered palm with reduced saturates, increased monounsaturates in palm oil certainly can have future role!