Vegetable oil usage in lubricants

Ilija Gawrilow

O

f 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. As environmental concerns grow, vegetable oils are finding their way into lubricants for industrial and transportation applications.

These oils offer significant environmental benefits with respect to resource renewability and 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.

The raw stocks exist for producing vegetable oil lubricants. Currently, over 125 million metric tons (MMT) of vegetable oils are produced worldwide. Formulating with vegetable oils—especially the highly saturated oils—does, however, present unique challenges. These are: low temperature viscosities, oxidative instability, and hydrolytic instability problems associated with the triglyceride.

Natural lubricants history

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 AD 50 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. Today, vegetable oils are drawing attention as biodegradable alternatives for synthetic esters as they are less expensive and are available from renewable sources.

Modern uses

Vegetable oils are frequently 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 oils
- Chain saw oils
- Hydraulic oils
- Mold release oils
- Farming, mining, and forestry equipment
- Open gear lubricants
- Greases
- Fuels

Lubrication issues

Fluidity of oil is mainly determined by the efficiency of molecular packing, intermolecular interactions, and molecular weight. Most of the vegetable oils that are readily available and inexpensive are not suitable for lubrication because of their high saturate or polyunsaturated fatty acid content. Saturated fatty acids have too high a level of crystalline symmetry, which facilitates interlocking of the sharp needle-like triacylglycerol crystals as temperature decreases.

Monounsaturated fatty acid oils present optimum oxidative stability and lower temperature properties. Vegetable oils with high stability and low pour points—the temperature below which a liquid stops flowing—can be produced by converting all the fatty acids into monounsaturated fatty acids. Therefore, base fluids for lubricants must have a balance of fatty acids, preferably a high level of monounsaturated, minimal polyunsaturates, and ideally, no saturates at all for use in cold climates.

Table 1 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 that mineral oils are more responsive to pour point depressant additives as these were developed for the paraffin waxes found in mineral oils, not the waxes found in most vegetable oils.

There is no need to worry about the shortcomings of vegetable oils for lubrication. Mineral oil fluids also cannot meet most lubrication performance needs without additives. Available additives that enhance base fluids are antioxidants, detergents, dispersants, viscosity modifiers, pour point depressants, antitrust agents, rust and corrosion inhibitors, demulsifiers, foam inhibitors, thickeners, friction modifiers, and other additives such as dyes and biocides.

Desired vegetable oil characteristics

The world market for environmentally friendly lubricants is poised to grow in the next year. The greatest demand will be in Europe and Canada, countries with the utmost environmental awareness and regulation. The lubricant industry could take advantage of oilseed biotechnology to produce high-per-
many of the engine applications, vegetable demand for performance traits, and in are probably the most challenging and lubricants. The engine lubricant systems categories: engine lubricants and non-engine can be divided into two major cat-

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Automation, technology, and performance base oils that are compatible with the current stable of additives used in the lubrication industry.

Selection of vegetable oils for this industry will rely upon the oils having 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 IV of 50–130 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, for example palm oil, tend to cling to metal surfaces more effectively than mineral oils and therefore provide improved lubricity.

**Application testing**

Typically, a formulation is subjected to a number of screen tests to evaluate its efficacy in a particular application. Once a formulation passes most or all of the screen tests, it is tested in the actual end-use equipment. At the conclusion of the test, drains and parts are rated for sludge formation, acid build-up, deterioration in the formulation, wear, scuffing, weight loss, and so on. Each application has its own set of specific tests and adheres to them very closely.

**Potential markets**

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<table>
<thead>
<tr>
<th>Oil</th>
<th>Viscosity 40°C cSt</th>
<th>Viscosity 100°C cSt</th>
<th>Viscosity Index</th>
<th>Pour Point °C</th>
<th>Flash Point °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut oil</td>
<td>27.7</td>
<td>6.1</td>
<td>175</td>
<td>-18</td>
<td>252</td>
</tr>
<tr>
<td>350 Neutral mineral oil</td>
<td>65.6</td>
<td>8.4</td>
<td>97</td>
<td>-18</td>
<td>346</td>
</tr>
<tr>
<td>Low erucic rapeseed oil</td>
<td>36.2</td>
<td>8.2</td>
<td>211</td>
<td>-18</td>
<td>252</td>
</tr>
<tr>
<td>High oleic sunflower oil</td>
<td>39.9</td>
<td>8.6</td>
<td>206</td>
<td>-12</td>
<td>252</td>
</tr>
<tr>
<td>Conventional soybean oil</td>
<td>28.9</td>
<td>7.6</td>
<td>246</td>
<td>-9</td>
<td>325</td>
</tr>
<tr>
<td>Palm oil</td>
<td>39.7</td>
<td>8.2</td>
<td>188</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

| Table 1 Properties of vegetable oils compared to mineral oil

Gear oil lubricants

The driving force for vegetable oil use in this application is because it is considered a “loss” lubricant and thus a threat in environmentally sensitive areas. The market trend is toward segmentation to higher and lower quality products. The largest potential areas for use are: marine (especially outboard engines), mining, agricultural, and food machinery.

Potential market size: 50,000 MT (open gear), 40,000 MT (closed gear)

Metalworking fluids

High stability liquid vegetable oils appear to be well suited for applications where neat oils and varnish is problematic, such as aluminum casting and rolling. The high sta-

Hydraulic fluids

Antwear hydraulic fluids represent the largest potential market growth for vegetable oils. Immediate markets are Canada and Europe, with the U.S. market to trail development and usage of these types of systems. The key aspect for growth in this area is to demonstrate higher performance and value as compared to other commodity oils.

For this application, benefits are: good biodegradability 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. However, poor thermal and oxidative stabilities are of concern. To be successful, a producer would need to partner with a major oil company who manufactures and distributes hydraulic fluid.

Potential market size: 350,000 MT with realistic short-term market of 10,000 MT

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**Lubricants can be classified into two general categories as engine and non-engine.**

| Engine Lubricants                     | Non-engine
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Gasoline engine oils</td>
<td>Transmission fluid</td>
</tr>
<tr>
<td>Diesel engine oils</td>
<td>Power steering fluids</td>
</tr>
<tr>
<td>Automotive diesel oils</td>
<td>Shock absorber fluids</td>
</tr>
<tr>
<td>Stationary diesel oils</td>
<td>Gear oils</td>
</tr>
<tr>
<td>Railroad diesel oils</td>
<td>Hydraulic fluids</td>
</tr>
<tr>
<td>Marine diesel oils</td>
<td>Tractor fluids</td>
</tr>
<tr>
<td>Natural gas engine oils</td>
<td>Industrial fluids</td>
</tr>
<tr>
<td>Aviation engine oils</td>
<td>Metalworking fluids</td>
</tr>
<tr>
<td>Two-stroke engine oils</td>
<td>Greases</td>
</tr>
</tbody>
</table>

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. Use of vegetable oil based lubricants is already mandated in Europe, and the requirement is taking hold in other regions of the world as well. Cost issues will always remain and market growth will accelerate when governmental legislation is enacted. The vegetable base oil needs to have good low temperature properties, good oxidative stability, and good miscibility with gasoline.

Potential market size: 50–70,000 MT
bility 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 U.S. metalworking plants are under pressure from the government on their waste-water discharge and from worker’s unions regarding worker exposure.

Potential market size: 540,000 MT

Textile lubricants
Certain vegetable oils are used in textile and fiber manufacture to lubricate fibers and make them tolerate processes such as spinning and weaving. 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.

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. Similar to other lubrication areas, both environmental concerns and health issues will encourage and accelerate the conversion to vegetable oil based lubricating systems.

Potential market size: 45,000 MT

Grease base fluids
This is a specification driven market where manufacturers want more packages, fewer components, and product differentiation. Environmental forces are not a factor, but could be a significant selling point if performance levels are maintained with vegetable oil products. Highest needs for, or best fit for products, are in mining, agriculture, and railroad. The vegetable oil with the best price and performance will capture this market.

Potential market size: 1 million MT

Food machinery lubricants
Food processing is a $500 billion industry in the United States alone; $2.8 billion of this amount is food production machinery. All of the equipment—conveyors, mixers, canners, cappers—have a steady appetite for lubricants. Palm oil and palm olein are highly suitable for this application, as they have good adhesion to metal surfaces, can be easily applied as palm oil has a melting point of 33°C–36°C, and resistance to oxidation.

Potential market size: Over $700 million a year just in the United States

Chain bar lubricants
This market segment requires very little technology and basically can use any oil with an added tackifier for the oil to stay on the bar of the chain saw. It is an established market and based on cost. There is minimal cost to be in this market but to be successful a company must be able to differentiate their product or oil from the rest of the field.

This is an area that will probably have future legislation requiring its use. There are no industry specifications and each company sets its own standards. Areas of importance for these oils are viscosity at 40°C and 100°C, VI, pour point, flash point, and tackiness.

Potential market size: 45,000 MT
Metalworking
Steel and aluminum foundries use lubricants that are designed to tolerate high temperatures, withstand severe vibration and shock, and undergo consistently high loads. Rolling mills, furnaces, and foundries are hostile environments and need to be treated with respect. Lubricants used must also meet the highest safety standards, as well as being non-toxic and environmentally friendly. There is a market for hot and cold rolling oils, particularly for the aluminum industry for hot rolling, and cutting oils. Good stability and excellent pressure performance are required of lubricants in this industry.

For the steel industry, an advantage of vegetable oils is that residue from oil remaining on the surface after burn off provides a brighter and shinier surface.

Forecast
Although the overall global picture for lubricants is glum due to mature markets, low volume growth, and declining demand in certain regions, there is an overall opportunity in terms of qualitative growth; that is, innovation in products, services, and systems.

Criteria that would encourage increased use of vegetable oil based lubricants are:
- Prices equal to or lower than conventional products
- New legislation
- Technical performance equals or exceeds conventional products
- More product information from suppliers
- Recommendation from occupational and environmental medical specialists

This certainly includes novel vegetable oil lubricants, 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 and increased monounsaturates certainly can have a future role.

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