Eco-Based Lubricants & Greases: A Study that Looks at both Sides of the Coin

Authors: Henry Takizawa, Dr. Raj Shah

KOEHLER INSTRUMENT COMPANY, INC.

Abstract

The importance of environmentally sustainable products has become paramount in recent years due to the adverse effects of climate change on our environment. As more and more countries push for legislation regulating the use of fossil fuels and their related byproducts, it has become a challenge for companies within these industries to find eco-friendly alternatives to fossil fuels that provide the same quality of product and are also economically viable. The research conducted for this paper will be used to discern the advantages and disadvantages of bio-lubricants and to ultimately determine if they can be used as a viable substitute to conventional mineral based lubricants. There are always pros and cons related to a sea change and moving to biolubricants and greases in lieu of conventional products is no exception. In this paper we will evaluate both sides of the coin, looking at the real versus perceived environmental benefits, potential applications, and means of production surrounding vegetable oil based lubricants (and greases) to see if they are really sustainable products. We will also study the applicability of these bio-based lubricants in the conditions and environments where conventional lubricants are commonly used and see how they perform.

Introduction

Lubricants are primarily used in industry to decrease the friction between two surfaces in contact with each other. They serve multiple functions such as transporting foreign particles trapped between surfaces, preventing wear on the surface material and dissipating heat generated by the equipment. They are composed of majority base and are supplemented with additives to improve their functionality based on their specified use. Biolubricants are most often synthesized from vegetable oils using a process known as transesterification. Depending on which base oils and alcohols are used, a variety of different lubricants can be produced with distinct chemical and physical properties. The primary properties that affect the performance of a lubricant are thermal stability, viscosity index, pour point, flash point, resistance to corrosion, and resistance to oxidation.

Additive	Function	Example
Antioxidant	Improve oxidation resistance	Diphenylamine
Corrosion inhibitor	Protect against chemical attack	Sulphurized terpenes
Rust inhibitor	Prevent corrosion of ferrous materials	Amine phosphates
Antiwear	Reduce wear	Ethyl stearate
Antifoam	Prevent foaming	Polydimethylsiloxanes
Extreme pressure	Prevent welding	Cetyl chloride
Friction modifier	Prevent oscillations and noise	Ethers
Viscosity index improver	Improve viscosity-temp. relation	Polyisobutylene
Emulsifier	Disperse water in base oil	Naphthenic acids
Thickener	Converts oil into solid or semisolid lube	Calcium soap
Detergents	Disperse particulate matter	Phenates
Pour point depressant	Affect fluidity by controlling crystal formation	Polyalkyl methylacrylates

Table 1. Commonly Used Additives in Lubricant Manufacturing[5]

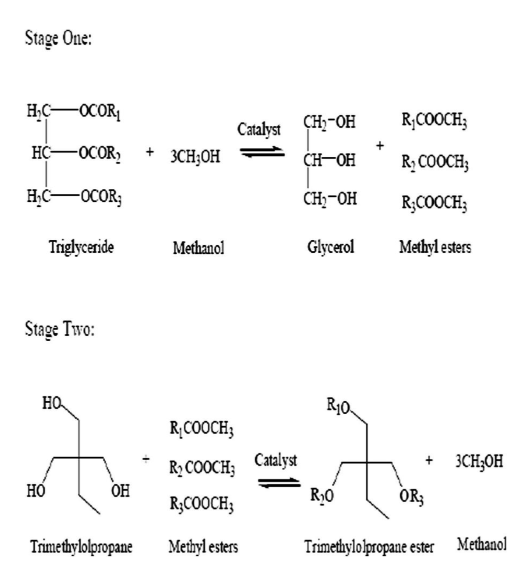

Fig. 1. Transesterification reaction[6]

Comparison of Characteristics

A good lubricant is defined by its ability to perform its intended functions over a broad range of temperatures and conditions. Although solid lubricants do exist, liquid lubricants are more commonly used in industry so this study will be looking at a comparison of multiple plant based and mineral based liquid lubricants and their properties. Ideally, a liquid lubricant should have a low pour point and a high flash point. Additionally, a high viscosity index is desired so that the viscosity of the lubricant does not vary significantly with temperature. A high oxidative stability is also important for the longevity of a lubricant's use.

Lubricant requirement	Viscosity 40°C (cSt)	Viscosity 100°C (cSt)	Viscosity index	Pour point (°C)	Flash point (°C)	Oxidative stability (min)	Coefficient of friction	Wear scar (mm)
ISO VG32	>28.8	>4.1	>90	-6	204	-	-	-
ISO VG46	>41.4	>4.1	>90	-6	220	-	-	-
ISO VG68	>61.4	>4.1	>198	-6	226	-	-	-
ISO VG100	>90.0	>4.1	>216	-6	246	1670.26	-	-
Paraffin VG95	95	10	102	-	-	-	-	-
Paraffin VG460	461	31	97	-	-	-	-	-
R150	150.04	-	-	-	195	931.16	-	-
SAE20W40	105	13.9	132	-21	200	-	0.117	0.549
AG100	216	19.6	103	-18	244	-	-	-
75W-90	120	15.9	140	-48	205	-	-	-
75W-140	175	24.7	174	-54	228	-	-	-
80W-140	310	31.2	139	-36	210	-	-	-
Vegetable oil								
Soybean	28.86	7.55	246	-9	325	-	-	-
Sunflower	40.05	8.65	206	-12	252	-	-	-
Passion fruit	31.78	-	-	-	228	7.5	-	-
Moringa	44.88	-	-	-	204	28.27	-	-
Castor	220.6	19.72	220	-27	250	-	-	-
Rapeseed	45.60	10.07	180	-12	240	-	-	-
Jatropha	35.4	7.9	205	-6	186	5	-	-
Coconut	24.8	5.5	169	21	325	-	0.101	0.601
Rice bran	40.6	8.7	169	-13	318	-	0.073	0.585
Palm	52.4	10.2	186	-5	-	-	-	-
Lesquerella	119.8	14.7	125	-21	-	-	0.045	0.857
Pennycress	40.0	9.3	226	-21	-	-	0.054	0.769

Table 2. Properties of commercial lubricant and vegetable oils[7]

From the table, it can be seen that vegetable oils tend to have higher viscosity indexes and flash points than mineral oils. However, they do not have very low pour points and their oxidative stability is substantially lower than those of mineral oils from the data that is shown. It appears that vegetable oils also have lower coefficients of friction than mineral oils, making them more efficient but they seem to leave more wear on the surfaces they work on.

Means of Production

Traditional mineral oil based lubricants are manufactured by extracting crude oil from fossil fuel deposits, refining that oil, and then processing the refined oil until it acquires the desired lubricant qualities. Manufacturing biolubricants is a more complex process. First, the crop has to be planted and harvested. The vegetable oil is then extracted from the plant/seed. Finally, the extracted oil is processed until it has the desired properties and characteristics. In order to fully grasp the scope of switching to the production of biolubricants from mineral lubricants, the environmental, economic and social impacts of every step must be taken into account.

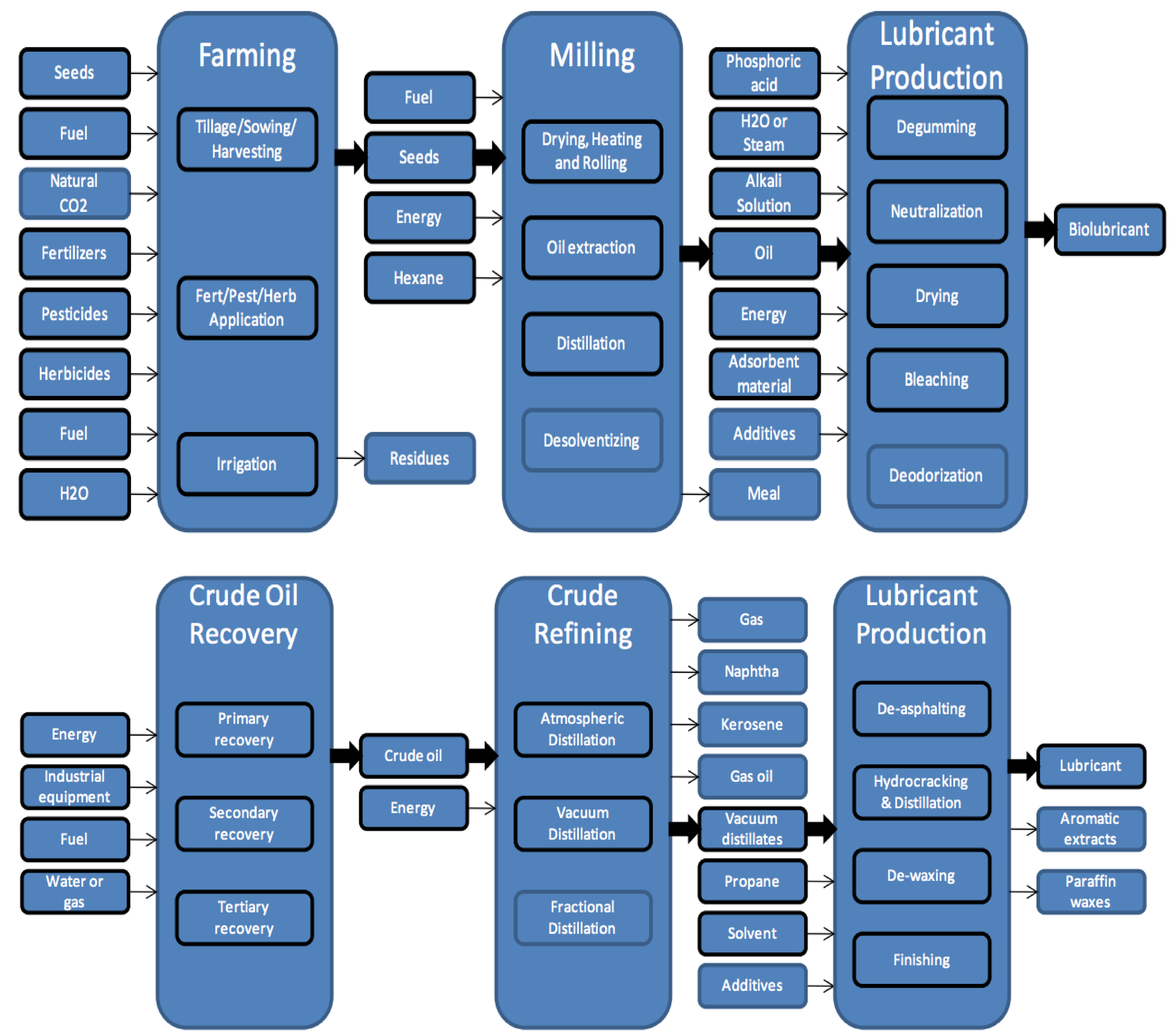

Fig. 2. Detailed life cycles of a biolubricant and a mineral based lubricant[5]

As is shown in figure 2, it is important to consider the usage of fertilizers, pesticides, and herbicides as well as the fuel consumption in the agricultural stage of biolubricant production. These products leak nitrogen and phosphorous into nearby bodies of water which can result in eutrophication which disrupts the stability of the ecosystem by stimulating excessive plant growth. In addition, the production of greenhouse gasses from fossil fuel combustion must also be taken into account when measuring the environmental impacts of switching to biolubricants.

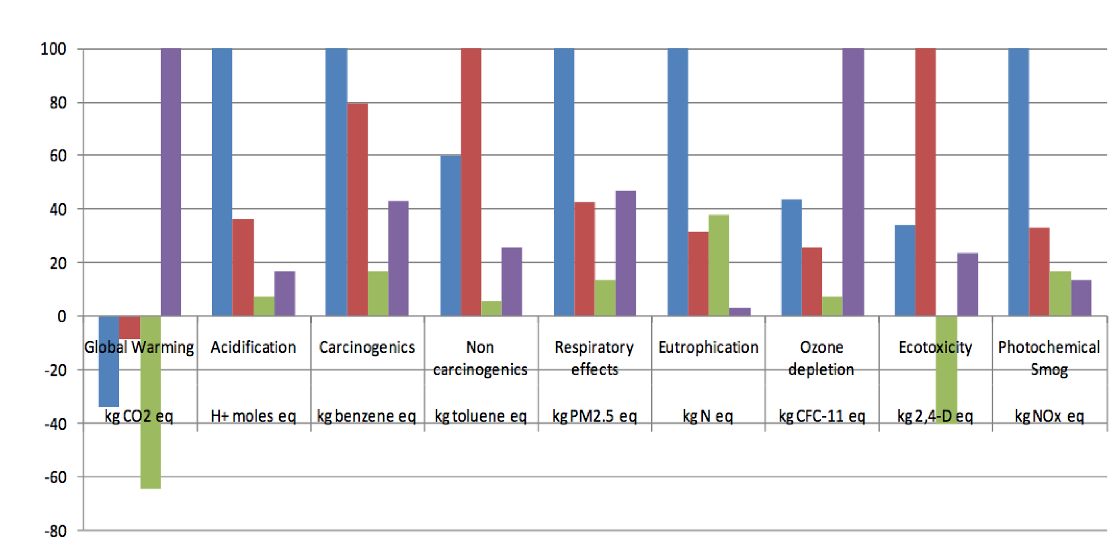

Fig. 3 Environmental effects of producing rapeseed lubricant, rape oil, soybean oil, & commercial lubricant[5]

In a Life Cycle Assessment (LCA) performed by Phoebe Cuevas, a Master's student at the University of Pittsburgh, data from a multitude of LCA's comparing the life cycles of various bio-based based lubricants to traditional lubricants were compiled to create this chart to analyze the various effects of manufacturing these biolubricants on our ecosystem. The chart shows that in the areas of Global Warming Potential and Ozone Depletion, mineral based lubricants had a much larger impact. However, in almost all other areas of environmentally hazardous potential, barring Eutrophication in the case of soybean oil, manufacturing biolubricants produced higher counts of harmful chemicals

Environmental Benefits

According to a 2010 study by the United States Environmental Protection Agency, an estimated 36.9 to 61 million liters of lubricating oil leaks into marine port waters every year. If you consider the larger estimate that is about the size of one and a half Exxon Valdez sized oil spills every year.

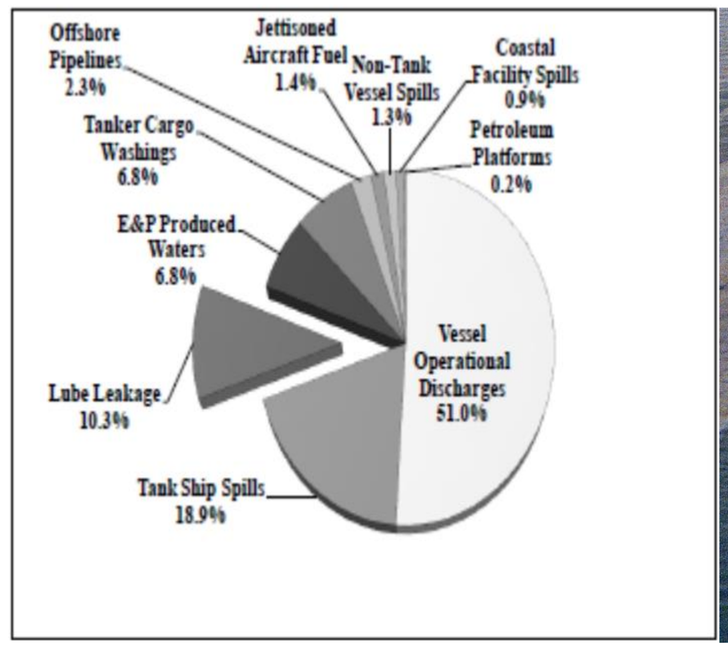

Fig. 4. Oil inputs into marine environments[3]

Fig. 5. Photograph of Exxon Valdez Oil Spill[8]

However, lubricant leakage only results in about 10% of total oil inputs into marine waters which presents an alarming environmental and economic issue. Not only does this put millions of marine organisms at risk, but it is estimated that the total annual response and damage costs of these oil inputs reaches $322 million globally. Bio-based lubricants are readily biodegradable due to the nature of their base oils, and can save considerable costs in clean up as well as significantly decrease the harm caused to these marine habitats.

Lubricant base oil	Base oil source	Biodegradation	Potential for Bioaccumulation	Toxicity
Mineral oil	Petroleum	Persistent / Inherently	Yes	High
Polyalkylene glycols (PAG)	Petroleum - synthesized hydrocarbon	Readily	No	Low[a]
Synthetic Ester	Synthesized from biological sources	Readily	No	Low
Vegetable Oils	Naturally occurring vegetable oils	Readily	No	Low

Table 3. Biodegradability and toxicity of mineral oil vs. EPA environmentally acceptable lubricants[3]

Additional Considerations

In order to fully comprehend the impact of a worldwide conversion from mineral lubricants to biolubricants, it is absolutely essential to acknowledge the sheer amount of agricultural land needed to make such a decisive change possible as well as the market impacts of potentially changing bulk of crops being produced. Currently the primary use of the majority of agricultural land is food production. There is a conversation to be had on the effects of designating a portion of this land for the production of biochemicals on food prices and the tariffs placed on crops. However, it is impossible to know exactly what these effects will be nor how significant a challenge they may pose unless more research is done on which crop or crops should be used for biolubricant production and if they can grow properly in the climates already designated for agricultural land use. A number of crops including rapeseed, soybean and palm have been considered for biolubricant manufacturing due to the physical properties of their extracted oils but whether or not they can be efficiently grown without causing more harm to the environment then they are preventing is still up for debate.

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