THE USE OF SOYBEAN OIL IN BIOBASED PRODUCTS

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Introduction

The search for environmentally friendly materials that has potential to substitute mineral oil in various industrial applications is currently being considered a high priority research in the fuel and energy sector. This emphasis is largely due to the rapid depletion of world fossil fuel reserves and increasing concern for environmental pollution from excessive mineral oil use and their disposal especially in loss lubrication, military applications, and in outdoor activities such as forestry, mining, railroads, fishing and agriculture hydraulic systems. It has been reported that more than half of the lubricants that are sold worldwide pollute the environment due to total-loss lubrication, spillage and through evaporation (Horner, 2002). The demand of biodegradable lubricants is increasing due to a rapidly growing concern for the impact that our technology is making to our environment. This concern is occurring as a result of local and national regulations, and consumer influence. European countries are leading the efforts in this area (Miles, 1998).

An opportunity to accelerate the development of this market in U.S. exists in the 2002 Farm Bill (Farm Security and Rural Investment Act, published January 11, Federal Register). Section 9002 includes language directing all Federal Government Agencies to give preference to "Biobased" products, unless it is unreasonable to do so, based on price, availability or performance. Biobased products are industrial products (including fuels but not food or feed) made from renewable agriculture and forestry resources. One of the main application areas of this effort is in the area of lubricants.

Vegetable oils as lubricants are preferred because they are biodegradable and non-toxic, unlike conventional mineral-based oils (Randles et al., 1992). They have very low volatility due to the high molecular weight of the triglyceride molecule and have a narrow range of viscosity changes with temperature. Polar ester groups are able to adhere to metal surfaces, and therefore, possess good boundary lubrication properties. In addition, vegetable oils have high solubilizing power for polar contaminants and additive molecules.

On the other hand, vegetable oils have poor oxidative stability primarily due to the presence of bis-allylic protons and are highly susceptible to radical attack and subsequently undergo oxidative degradation to form polar oxy compounds (Becker et al., 1996). This phenomena result in insoluble deposits and increases in oil acidity and viscosity. Vegetable oils also show poor corrosion protection. The presence of ester functionality renders these oils susceptible to hydrolytic breakdown. Therefore, contamination with water in the form of emulsion must be prevented at every stage. Low temperature study has also shown that most vegetable oils undergo cloudiness, precipitation, poor flow, and solidification at -10°C upon long-term exposure to cold temperature in sharp contrast to mineral oil-based fluids. Not all vegetable oils possess equivalent chemical and performance properties. Mixing of renewable oils will be required to serve the major market of lubricants. There is limited data available on blending of vegetable oils.

This study presents a systematic approach to improve the oxidation and cold flow behavior of vegetable oil derivatives using synergistic combination of additives in high-oleic vegetable oil blended with synthetic fluid.

Materials and Methods
Materials:

Soybean oil (SB) used in this study was alkali refined (ADM Packaged Oils, Decatur, IL) and used without any further purification. High-linoleic soybean oil (HLSB), mid-oleic soybean oil (MOSB) from United Soybean Board, high-oleic soybean oil (HOSB) from Optimum Quality Grains, LLC, West Des Moines, IA, high-oleic safflower oil (HOSF), high-oleic sunflower oil (HOSN) from Spectrum Ingredients, Petaluma, CA, and polyalphaolefin (PAO) from BP, Naperville, IL, were used in this study. The additives zinc diamyl dithiocarbamate (ZDDC) and antimony dialkyldithiocarbamate (ADDC) were obtained from R.T. Vanderbilt, Norwalk, CT.

Methods:

Pressure Differential Scanning Calorimetry (PDSC) Method. The experiments were done using a DSC 2910 thermal analyzer from TA Instruments (New Castle, DE) attached to a computer.

Pour Point Method. Pour points were measured by following the ASTM D97 (ASTM method, 2000) method.

Results

The vegetable base oils used in this study were selected to provide a wide variation in oleic acid percentage (Table 1).

Table 1. Fatty acid composition of various soybean oils by GC (AACC, 58-18, Approved methods of the American Association of Cereal Chemists, 10th edition, vol. II, 2000).

Vegetable oils	Palmitic C16:0 %	Stearic C18:0 %	Oleic C18:1 %	Linoleic C18:2 %	Linolenic C18:3 %	UN
SB	11.14	4.77	24.20	53.60	6.29	1.50
HLSB	10.61	5.63	27.49	56.27	-	1.40
MOSB	9.13	4.33	60.71	24.18	1.65	1.14
HOSB	7.08	3.30	86.78	1.08	1.76	0.94
HOSF	4.82	2.03	80.27	12.87	-	1.06
HOSN	3.27	2.86	89.11	4.76	-	0.99

The oxidation stability of various neat vegetable oils was determined as their onset temperatures (OT) using PDSC and is shown in Table 2.

Table 2. PDSC onset temperatures (OT) of vegetable oils and their PAO blends with and without additive mixture.

Vegetable oils	Onset Temperature (°C)			
	Neat oils	20%PAO8 blend	Neat oils + Additive	20%PAO8 blend + Additive
PAO8	188.0			
SB	172.9	173.9	215.0	226.6
HLSB	179.2	184.6	235.8	241.8
MOSB	190.3	191.5	243.1	250.4
HOSB	197.7	199.7	254.4	256.5
HOSF	177.4	187.9	257.1	260.4
HOSN	193.2	198.5	260	264
COM			244.2	

Polyalphaolefin (PAO) is oxidatively more stable base fluid with onset temperature of 188°C compared to 173°C of SB (Table 2). Therefore PAO was blended as diluent in various vegetable oils in 20-40% range. There is some increase in oxidation stability as seen from increased OT (Table 2) and improvement in low temperature stability on adding 20% PAO, but higher amount of PAO does not help. In this study, it was concluded that in soybean oil, the combination of ZDDC as antioxidant and ADDC as antiwear additive provides the best result. Figure 1 shows the oxidation induction time (OIT) of vegetable oil and their PAO blend based lubricant formulations containing additive mixture using PDSC isothermal experiment.

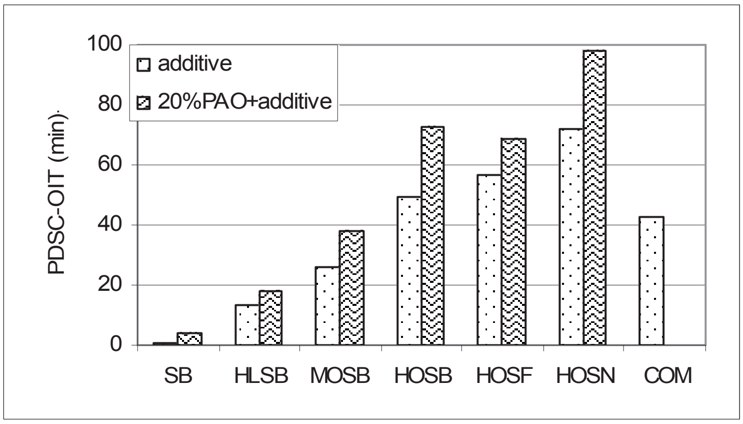

Figure 1

Figure 2 summarizes the pour points of vegetable oil and their PAO blends with and without the pour point depressant (additive). SB, HLSB and MOSB have a pour point of -9°C, whereas high-oleic oils have pour points in the range of -18 to -24°C.

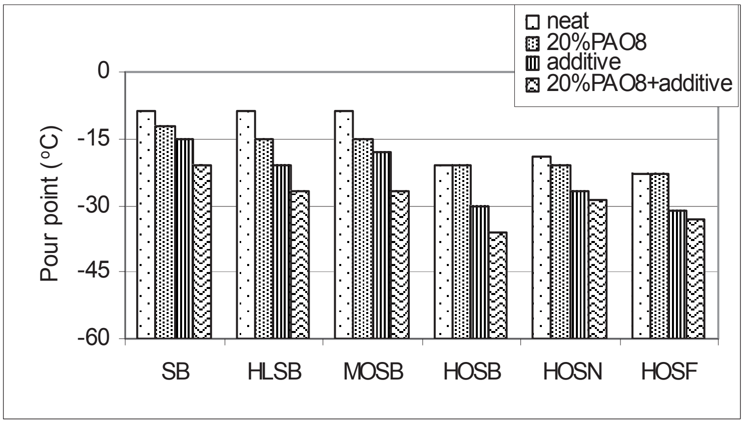

Figure 2

Conclusions

Thermo-oxidative stability and cold flow property can be best improved using the combination of chemical additives and high-oleic vegetable oils. The formulations with mid-oleic soybean oil also shows excellent thermo-oxidative stability and low temperature flow property when blended with PAO and suitable additive combinations, and is acceptable for most industrial applications. The lubricants formulated using the above approach exhibit superior oxidative stability, and improved low temperature properties such as pour points compared to some of the commercially available industrial oils such as bio-based hydraulic fluids, biodegradable oils for heavy equipment and bio-based drip fluid for agricultural equipment.

BIBLIOGRAPHY

BECKER, R., KNOR, A. 1996. Lubrication Science 8, 95-117.
HORNER, D. 2002. Journal of Synthetic Lubricants 18(4), 327-346.
MILES, P. 1998. Journal of Synthetic Lubricants 15(1), 43-52.
RANDLES, S.J., WRIGHT, M. 1992. Journal of Synthetic Lubricants9, 145-161.