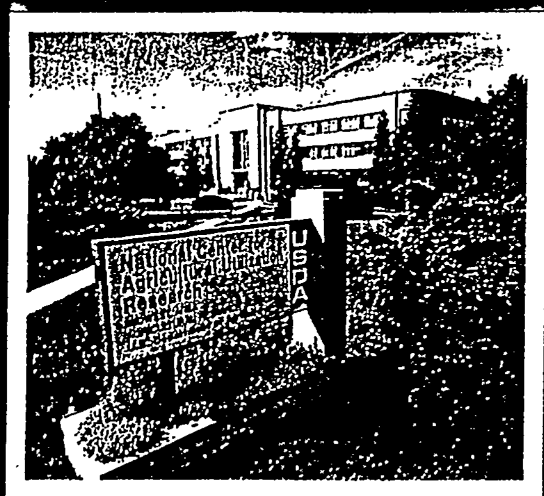
The Use of Vegetable Oils as Renewable Basestocks



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Lubricants and Hydraulic Oils

- Lubricant market in the U.S. is about $8 billion
- More than 90% of all lubricants are based on petroleum
- Hydraulic oils comprise about 10% of all lubricants
- The demand for biodegradable lubricants is expected to grow at about 10% annual rate

Concerns

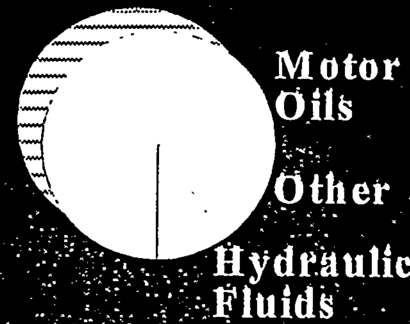
- Environmental
  - Pollution- Air, Water and Soil
  - Ecological Balance
- Handling and Toxicity
  - Health
  - Contamination
- Disposal
  - Biodegradability
  - Cost

Primary Functions of Lubricants

- Reduce friction and minimize wear
- Dissipate heat
- Disperse deposits
- Inhibit rust/corrosion
- Seal critical contact joints

Consumption of lubricants

~ 20 M tons / year in US



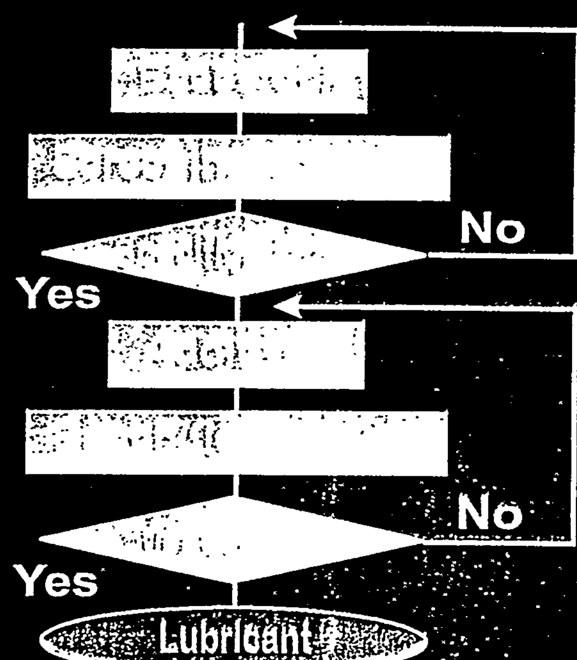
Commercial Uses of Biodegradeable Lubricants

- Chain saw lubricants
- Drilling oils
- Food industry fluids
- Gear oils
- Greases
- Hydraulic fluids
- Marine lubricants
- Pump oils
- Railroad lubricants
- Shock absorber fluids
- Mould release oils
- Two stroke engine oils

Biodegradability is delivered by **basestock**, not additives.

Basestock: 80-100% of Lubricant

Flowchart of Lubricant Development



Screening protocols depend on application

Basestock Screening

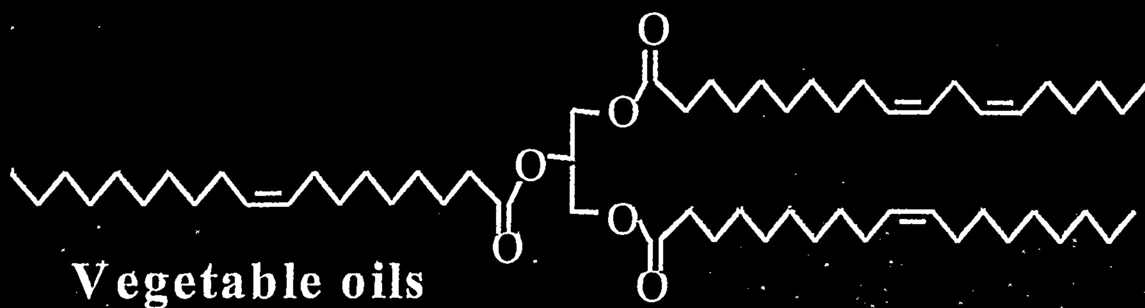
Lubricity more dependent on additives than on basestock

- Biodegradability
- Viscosity
- Low Temperature Solidification
- Volatility
- Oxidative Stability
- Deposite Forming
- Hydrolytic Stability
- Solvency / Miscibility
- Seal Compatibility
- Special Requirements
  (e.g. heat conductivity transparency, density, electric resistance, etc.)

Types of Additives Used in Lubricants

- Viscosity Index Improvers: (Few %)
- Oxidation Inhibitors: (0.5-1%)
- Detergent Dispersants (2-20%)
- Rust Inhibitors (~1%)
- Antiwear Agents (Few %)
- Pour Point Depressants (~1%)

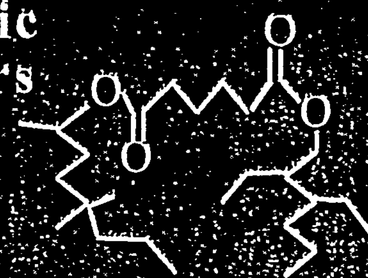
Options in biodegradable basestocks



Vegetable oils

Poly alpha olefins (PAOs)

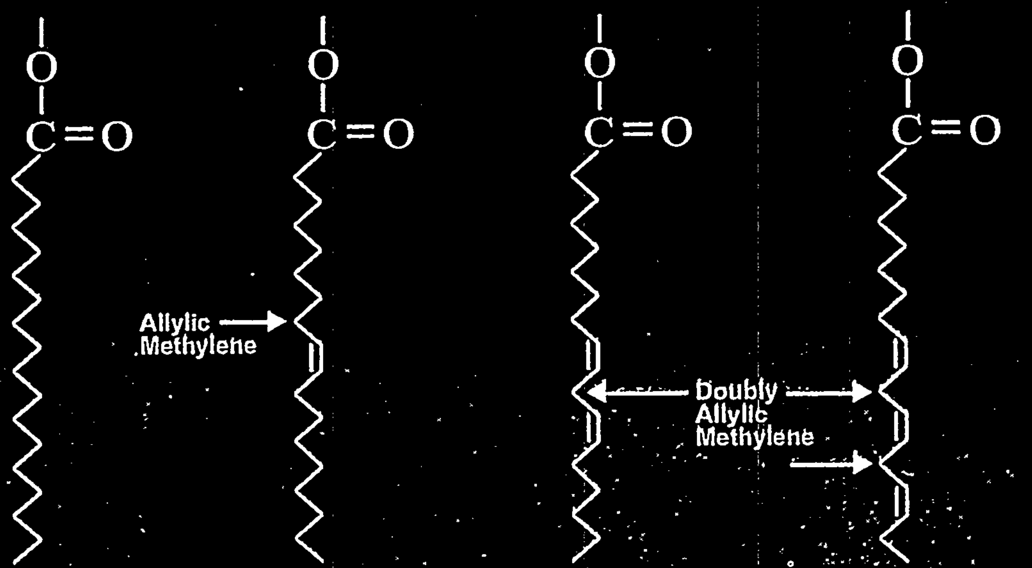
Synthetic Esters



Comparison of Major Basestocks

Base	$ / lb	Bio-degradability	Stability		Low T Performance
		CEC-L-33	Oxidative	Hydrolytic	
Vegetable Oils	0.5	95%+	Poor	Poor	Poor
Synthetic Esters	1.5	80%+	Good	Moderate	Excellent
Poly alpha olefins	1.0	70%+	Good	Excellent	Excellent
Mineral Oil	0.2	30%+	Good	Excellent	Good

Rate of Oxidation

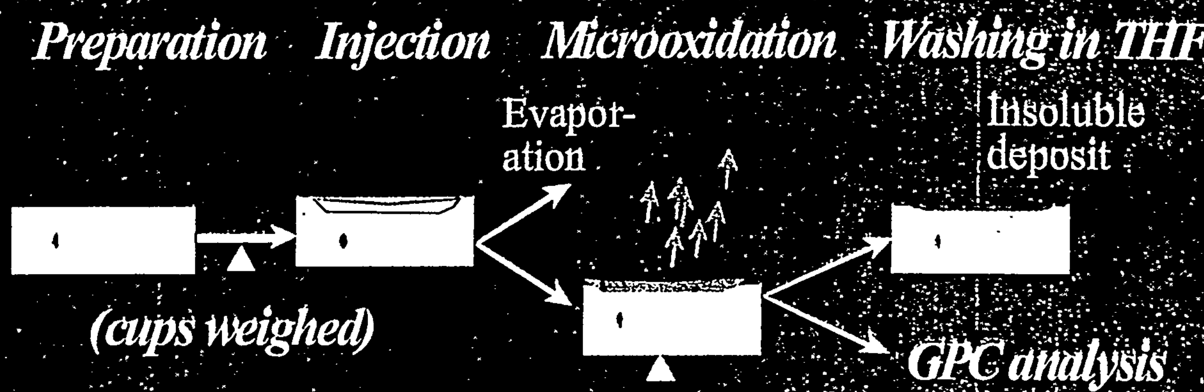


	Stearic (18:1)	Oleic (18:1)	Linoleic (18:2)	Linolenic (18:3)
Rate	1	10	100	200

Bond Dissociation Energies (D.E.)

Bond	Bond Type	Fatty Acid	D.E. Kcal/mole
CH_2 - H	Aliphatic	na	104
CH - H	Aliphatic	Stearic	96
CH = CHCH - H	Allylic	Oleic	85
CH = CHCH - H CH = CH	Doubly Allylic	Linoleic Linolenic	76

Sample analysis in micro oxidation

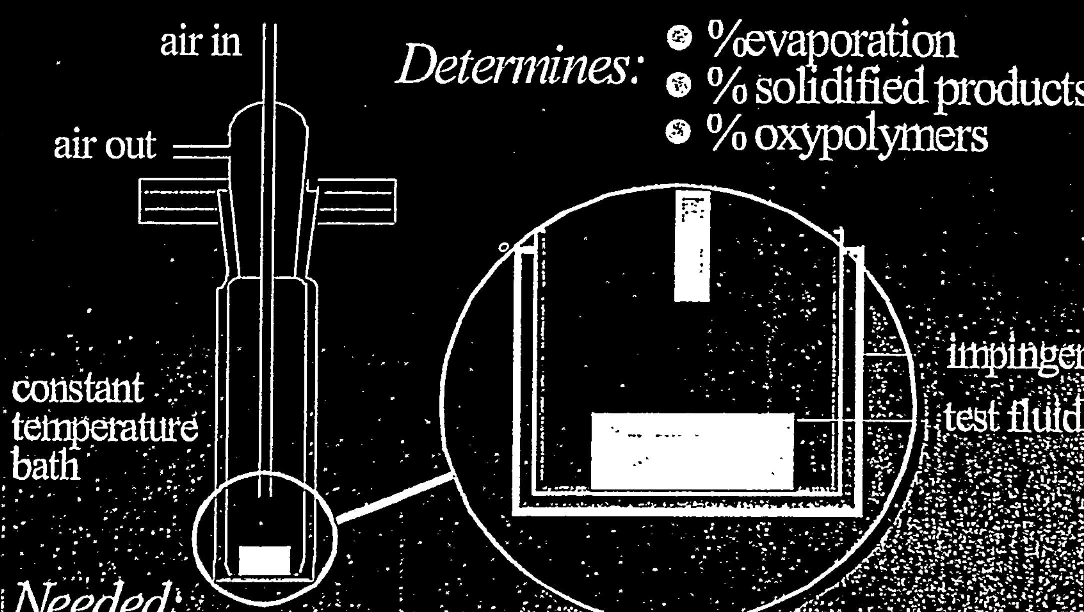


- %evaporation (negligible for vegetable oils)
- % solidified products
- % oxypolymers

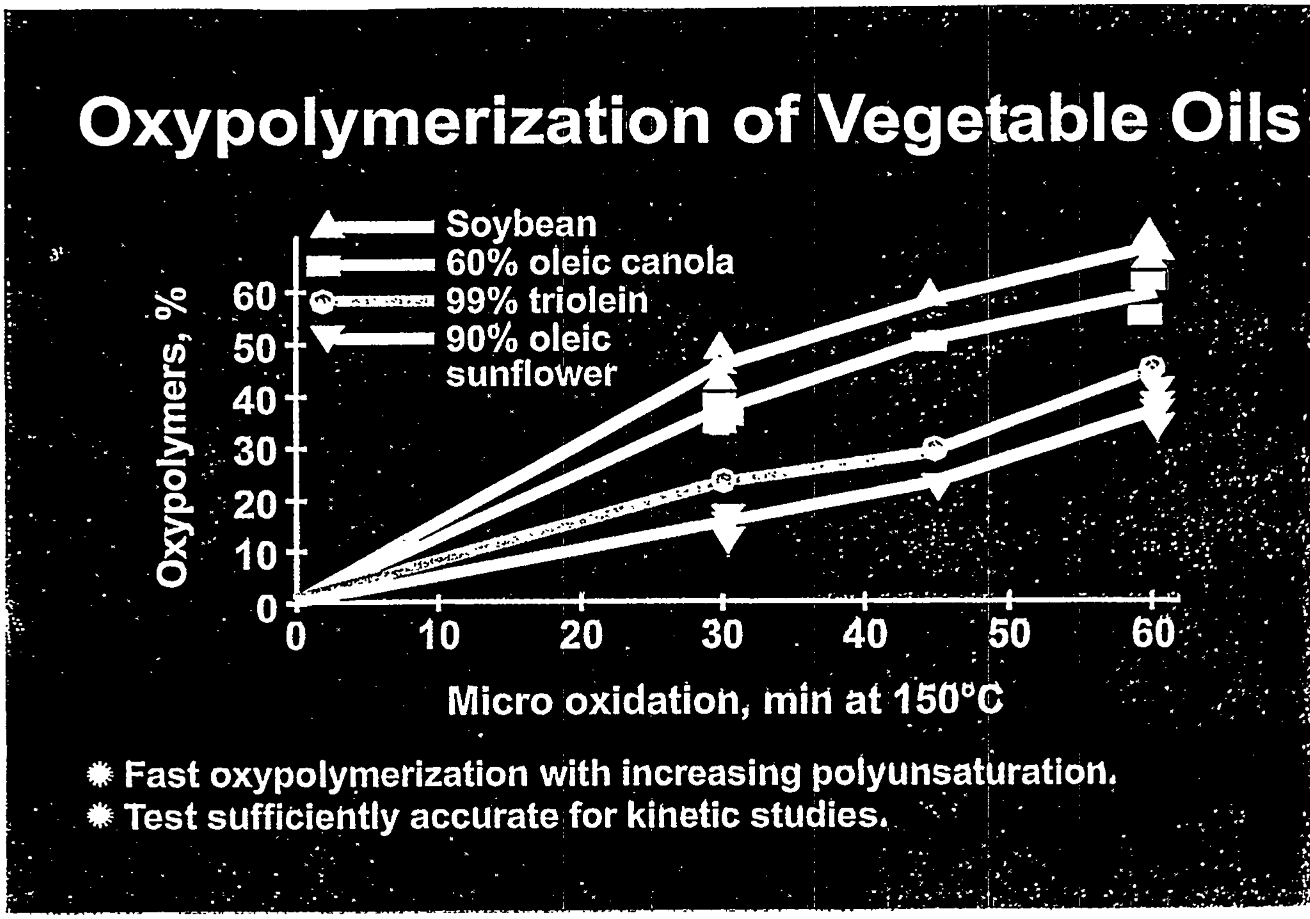
Investigating oxidative stability: micro oxidation

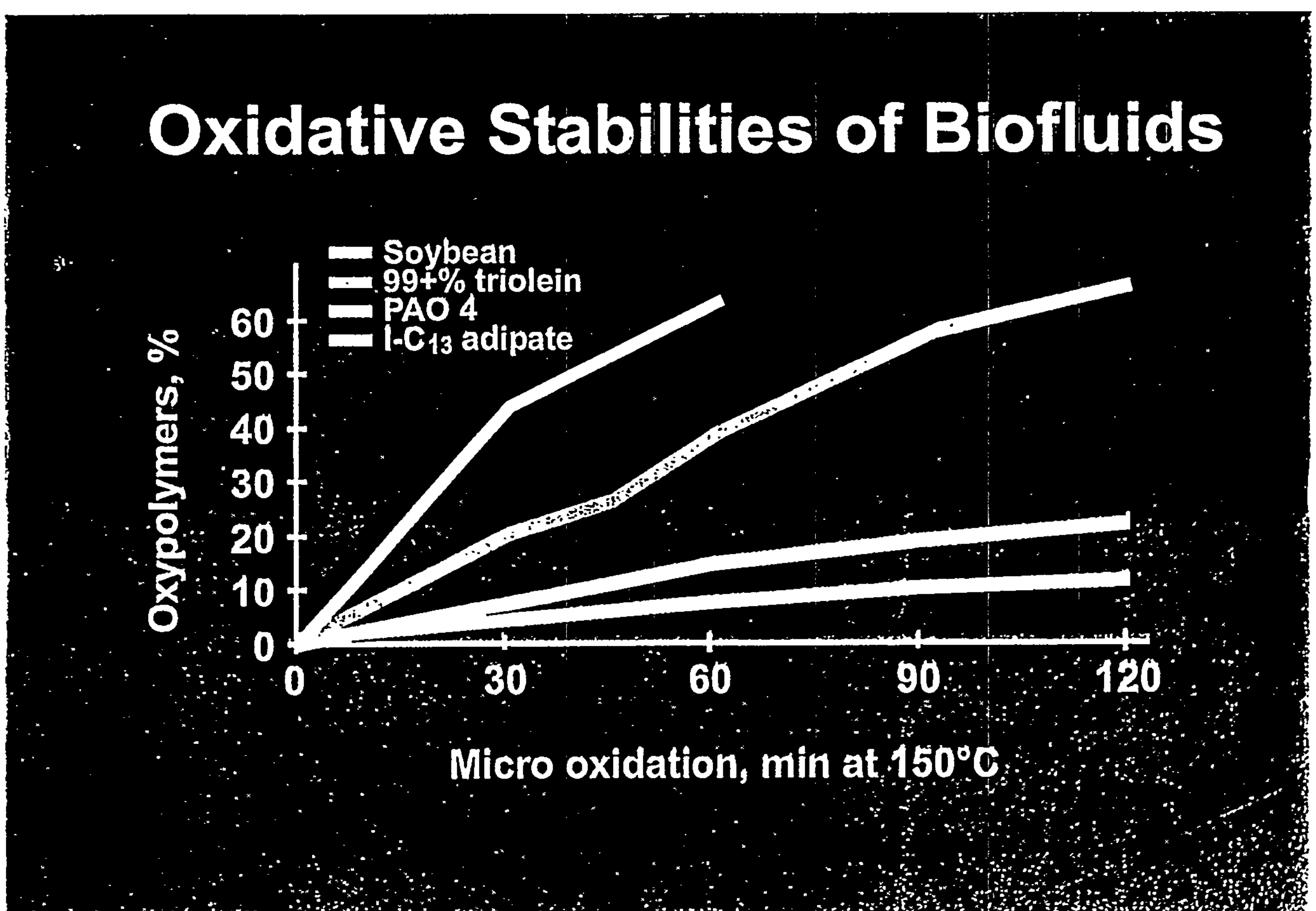
Determines:

- %evaporation
- % solidified products
- % oxypolymers

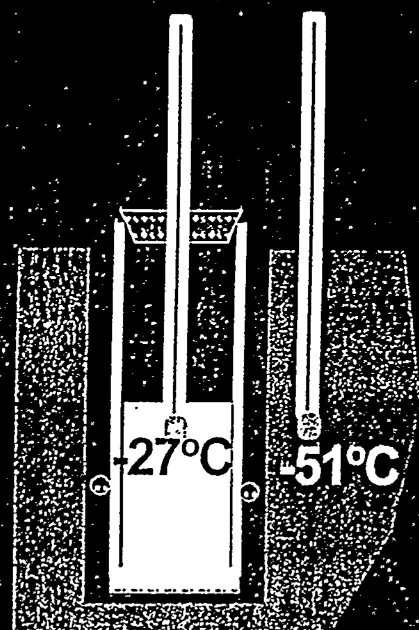


Needed:
low volatility and ox.stability better than in mineral oils


Oxypolymerization of Vegetable Oils
Soybean
60% oleic canola
99% triolein
90% oleic sunflower
Oxypolymers, %
0
10
20
30
40
50
60
0
10
20
30
40
50
60
Micro oxidation, min at 150°C
✹ Fast oxypolymerization with increasing polyunsaturation.
✹ Test sufficiently accurate for kinetic studies.


Oxidative Stabilities of Biofluids
Soybean
99+% triolein
PAO 4
I-C13 adipate
Oxypolymers, %
0
10
20
30
40
50
60
0
30
60
90
120
Micro oxidation, min at 150°C

Low temperature performance



ASTM D 97 Pour point and cold storage testing

Pour Point

Soybean oil - 9°C
90% oleic sunflower -12°C
Canola oil -21°C
Castor oil -24°C

Needed:
pour points below -36°C

no solidification at -25°C for 7 days

Mod. SBO Improves Low T Behavior

	Pour Point	Days at -25°C
VO* / diluent** (50:50)	-24°C	0
VO / diluent (50:50) + 1% PPD	-30°C	1
mod. SBO / diluent (50:50)	-18°C	0
mod. SBO / diluent (50:50) + 1% PPD	-36°C	7+
mod. SBO / diluent (65:35) + 1% PPD	-41°C	7+

* VO - high oleic (>80% oleic) Vegetable Oil
** diluent - low pour pt. polyalphaolefin or synthetic ester

Approaches to Improve the Drawbacks of Vegetable Oils

- Genetic modification to alter F.A.
- Chemical modification
  - Polymerization
  - Reduction
  - Branched chains (methylation)
  - Interesterification
- Separation techniques
  - Fractionation
- Formulation
  - Additive technology

Conclusions

- Government regulations restricting the use of petroleum lubricants provide an opportunity for vegetable oil based lubricants.
- Veg. oils are non-toxic, biodegradeable, renewable, and possess good boundary lubrication, a high viscosity index, a high flash point, low wear and a high load carrying capacity.
- High oleic vegetable oils with improved oxidative stability and low temperature properties show great promise as lubricant base stocks.
- Further improvements in genetic engineering and chemical modifications coupled with optimized additive technology will lead to a range of veg. oil products for environmentally sensitive markets.

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