Bio-based Product Line

Functional Products Inc.

May 15th 2019

Agenda

- Specialty lubricant additive lines
  - Biobased
    - What is it?
    - Relevant certifications / status
    - Advantages / challenges
    - Base oils supported
    - Viscosity modifiers
    - Additives & packages

Specialty Additives

- Standard petroleum lubricant products
  - Useful but not unique – commoditized; match specs and sell for less

- Specialty (biobased and food grade) lubricant additives
  - Useful and unique - compete on performance, opportunity

  - More specialized knowledge needed
    - More custom products, less interchangeability
      - Longer relationship with customer

  - More rules and exceptions about what is compatible / certifiable

What is Biobased?

- Formally: materials sourced from renewable, biological carbon
  - USDA BioPreferred program
  - European Ecolabel

- "Eco-Friendly" or an "Environmentally Acceptable Lubricant (EAL)"
  - Renewably sourced (ideally from sustainable vegetable oil)
  - Biodegradable
  - Non-toxic

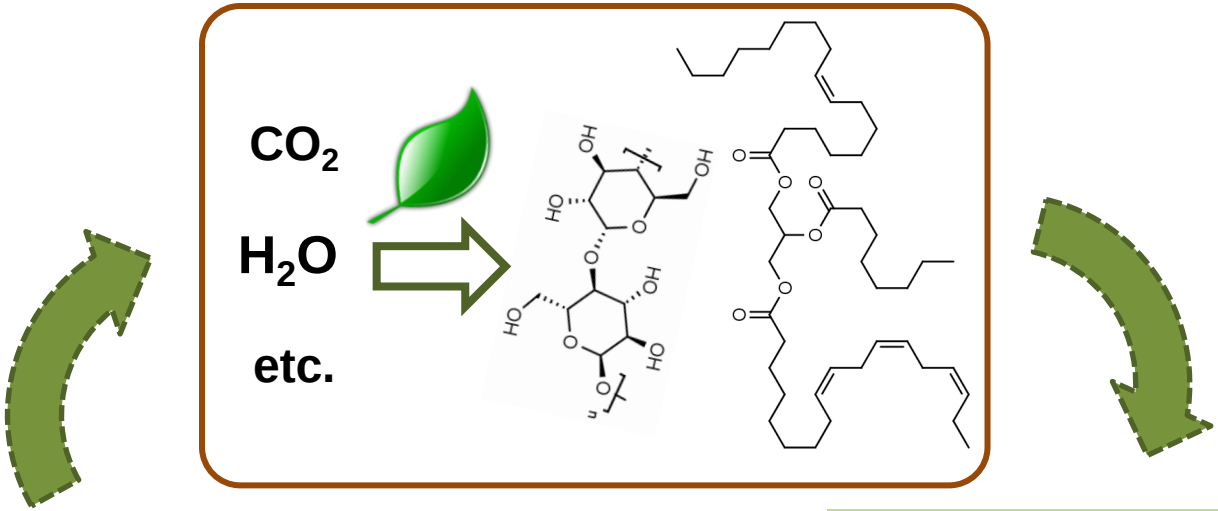
- May also include:
  - Highly biodegradable but non-renewable components like PAO 2
  - Additive packages, VM designed to thicken biodegradable lubricants

What is Biobased?

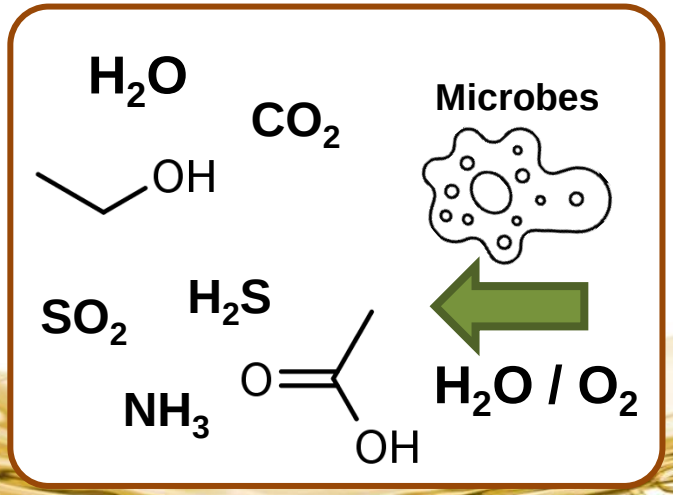
Biodegradable \ Biobased	No	Yes
Yes	PAO PAG	Vegetable Oil Synthetic Ester
No	Petroleum Oil	Ethanol-to-Ethylene Polymers

EAL Approach

Renewability



Biodegradability



Displace Petrochemicals

Ecolabel Program

- European program
  - Details requirements for lubricant additives and finished formulations
    - Dependent on likelihood of loss to environment
      - Rules changed in 2018 from initial 2014

  - Additives listed on “Lubricant Substance Classification List” - **LuSC**

Categorization by Lubricant Type		wt% Biodegradable*		wt% Renewable	
2014	2018	2014	2018	2014	2018
1 - Hydraulic Fluids, Tractor Oil	**Accidental Loss (ALL)**	>90% Readily <5% Unassessed	>90% Readily ≤5% Unassessed	>50%	Not required >25% to claim “bio-based”
2 - Grease, Stern tube Grease	+Closed gear, MWF	>75% Readily		>45%	
5 - Industrial/Marine Gear Oils	**Partial Loss (PLL)**	>90% Readily <5% Unassessed	>75% Readily ≤20%Unassessed	>50%	
4 - Two-Stroke Oil	+Corrosion coatings	>75% Readily <10% Unassessed		>50%	
3 - Chainsaw, Stern Tube Oil, Wire Rope, Concrete Release	**Total Loss (TLL)**	>90% Readily <5% Unassessed	>95% Readily ≤5% Unassessed	>70%	
	Any Grease		>80% Readily ≤15%Unassessed		

Terminology:

* *The balance wt% being inherently biodegradable.*

“Readily biodegradable” (aka “ultimately biodegradable”):
in 2018: 10 days, >70%, OECD 302; **in 2014**: 28 days, >60% loss by OECD 306/310 or >70% by OECD 301A
“Inherently biodegradable”: 28 days, 20-60% loss by OECD 306/310; >70% by OECD 302
“Unassessed”: Components considered “non-biodegradable, non-bioaccumulative” due to MW, particle size, solubility, etc.

Base Oils

- Natural Oils - Vegetable oil (soybean, canola, rapeseed, sunflower, etc.)

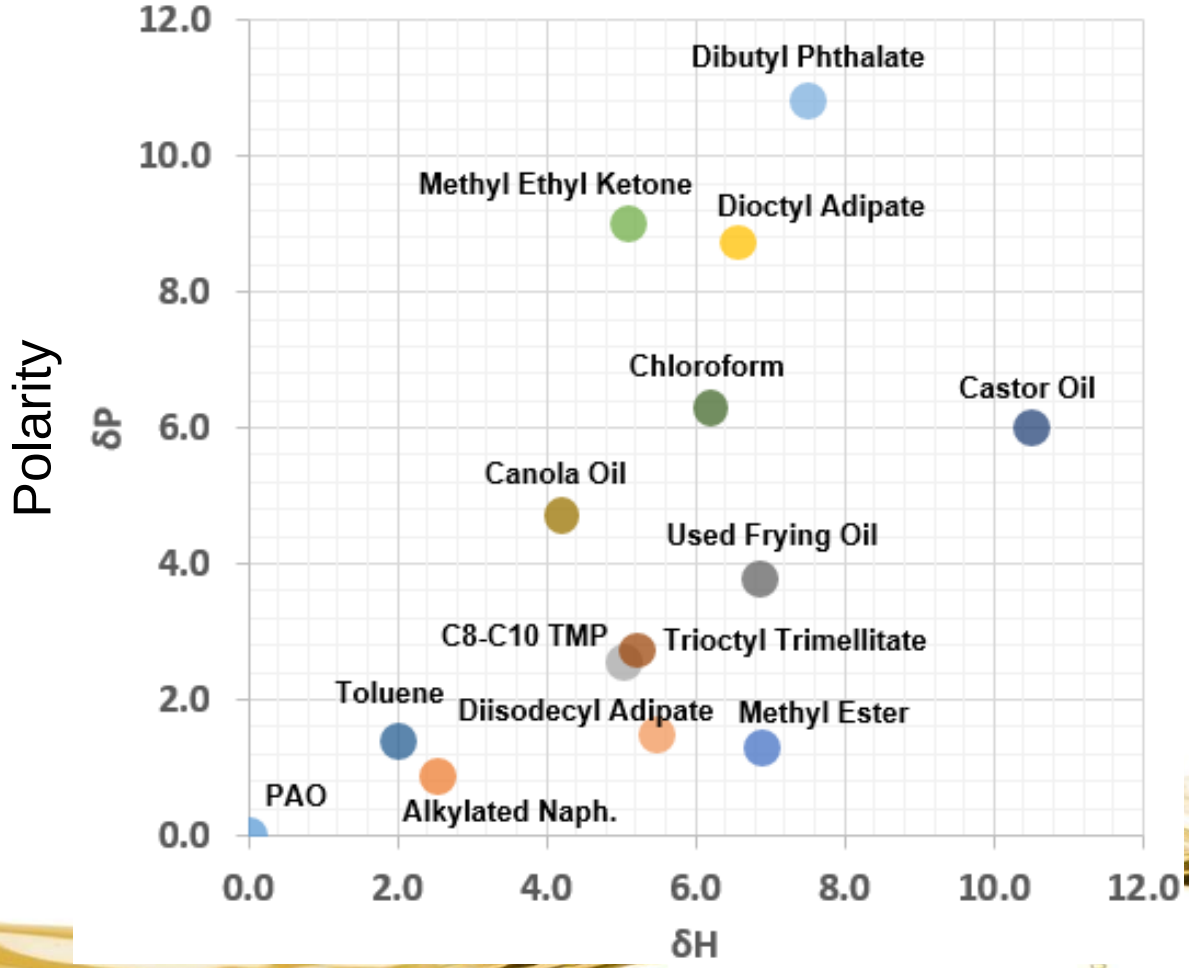
- Synthetic esters
  - Dibasic esters
  - Polyol ester: NPG / TMP / PE
  - Complex esters of multiple polyol / acids

- Biodegradable hydrocarbons
  - Low MW PAO
  - Proprietary branched alkanes

- *Water? *2019 STLE conference paper* Tuesday May 21, 9:30 Section 3K*

Solubility Map

- Solubility of VM, tackifier, additives is very case-by-case in biobased
  - Unlike petroleum products where everything is hydrogen + carbon



Biobased Advantages

- Very high viscosity index – good viscosity-temperature profile
  - Typically ISO 32 – 37 grade for Vegetable Oils
- Excellent low and high temperature options (pour point, flash point)
- Excellent lubricity from long chain fatty acid groups
- Niche markets
  - Required for marine / vessel applications
  - Often HX1 food contact, applicable to regulated industries

Biobased Challenges

- Cost
  - Vegetable oil more expensive than petroleum
- Stability
  - Hydrolysis of esters and formation of acids
  - Oxidation at C=C and C=O sites
    - Mitigated by more expensive saturated and branched esters
- Biological degradation
  - Some customers will not allow seed or vegetable oils into their facility
    - FPI can provide tolling services, given the business case
- Solubility of components

Tackifier

- Two main options for biobased tackifier
  - Some esters are compatible with tackifier but won't exhibit tack until high treat levels are used – V-572 recommended in those cases

Product	Role	Compatible In	Notes	LuSC
V-584	Tackifier	Veg oil, some esters	Proprietary tackifier for natural oils	Yes
V-572	Tackifier / VM	Veg oil, some esters, greases	Heavier duty tackifier and thickener Excellent in biobased greases.	No
V-515	Tackifier / VM	Veg oil, some esters	Viscosity modifier that will act as a shear stable tackifier at high treat levels	No

Viscosity Modifiers

- Many proprietary chemistries available
  - Each chemistry behaves differently

Product	Role	Compatible In	Shear Stability Index (D6278)	Notes	LuSC
V-508	Versatile VM	Veg oil, most esters	29	Most versatile chemistry for various ester base fluids. Poor low temperature < -20C. V-508F is in methyl ester, high visc.	**Yes**
V-521	Low Temp VM	Veg oil, many esters	30	Excellent thickener for low temp. synthetic esters – minimal change in pour point.	*TBA*
V-515	Economic VM	Veg oil, many esters	50	Excellent general purpose thickener; lowest treat. V-516 is in high oleic veg oil.	No

Grease Polymers

- Grease polymers formulated in biobased fluid or solid polymer
  - No mineral oils introduced

Product	Role	Compatible In	Notes	LuSC
V-4051	Grease polymer (reactive), Liquid	Petroleum and biobased grease	1-4wt% treat for excellent water resistance (<20% WSO) KV100 = 2000-3000 cSt, in ester	*TBA*
V-4020	Grease polymer (reactive), Pellet	Petroleum and biobased grease	0.25wt% treat for excellent water resistance	No
V-211	Grease polymer (styrene OCP), Flake	Petroleum and biobased grease	0.5-1wt% treat for excellent water resistance	No

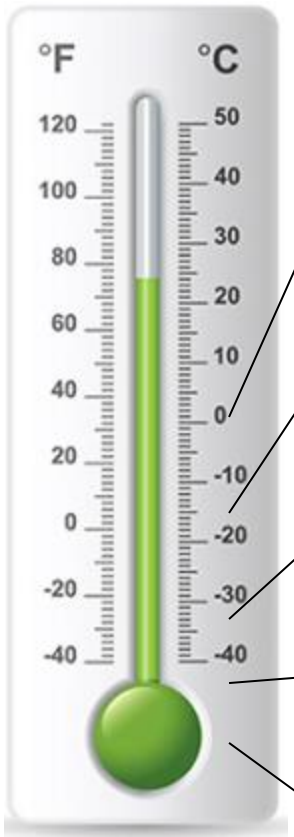
Pour Point Depressants

	Functional Products		Competitor
	PD-585	*PD-590*	*"E"*
KV100	1500	300	1800
Pour Point (wt%)			
0.0% in Canola	-24˚C	-24˚C	-24˚C
0.50% in Canola	-33˚C	-33˚C	-33˚C
1.00% in Canola	-36˚C	-33˚C	-33˚C
0.0% in Soybean	-12˚C	-12˚C	-12˚C
0.50% in Soybean	-21˚C	-18˚C	-21˚C
1.00% in Soybean	-24˚C	-21˚C	-21˚C
LuSC Listed?	No	**Yes**	No
EPA Safer Choice?	No	Yes	No

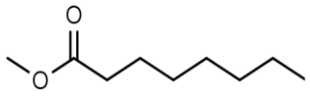
Differentiated by:

- Methacrylate ester distribution
- Handling viscosity
- Certifications, EAL

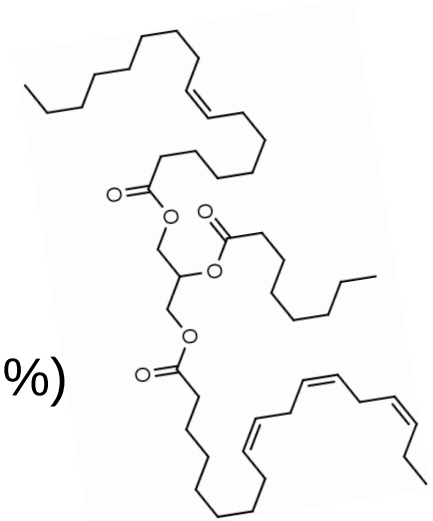
Low Temp Biobased



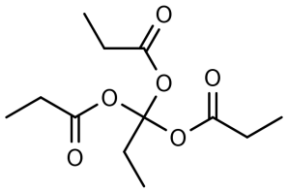
- 10°C to -10°C: methyl esters/oleates



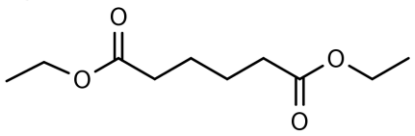
- -12°C to -24°C: veg oil



- -27°C to -36°C: veg oil w/ PPD (1%)
- -40°C to -50°C: TMP (TMPTO) and PE esters



- -60°C to -65°C: Adipate esters



Packages

- Chart updated for 2019

Additive Package Compatibility, by Base Fluid

						Paraffinic Oil					Ester				PAG		
	Treat/wt%	Light Color	Low Odor	Ecolabel/LuSC	MIL-PRF-32073	Group I	Group II	Group III	PAO / mPAO	Naphthenic Oil	Vegetable Oil	TMP Unsat.	TMP Sat.	Adipate	Oil Soluble	Water Soluble	Water Insoluble
Gear Oil Additives																	
GA-604	1.85%	•	•			•	•	•	•	•	•	•	•	•	•	•	•
GA-614	1.5-5.0%	•	•			•	•	•	•	•	•	•	•	•	•	•	•
Hydraulic Fluid Additives																	
HF-560	1.90%				•						•	•	•	•	•	•	•
HF-580	2.50%	•	•			•	•	•	•	•	•	•	•	•	•		•
HF-590	5.40%	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•
Way Oil Additives																	
WA-24	2.00%					•				•	•	•	•	•	•		
WA-64	1.75%	•	•			•	•	•	•	•	•	•	•	•	•		•
WA-60SF	1.50%	•	•			•	•	•	•	•	•	•	•	•	•		•
Rock Drill Oil Additives																	
RD-535	6.00%	•				•				•	•	•	•	•	•		
RD-535CP	6.00%	•				•	•	•		•	•	•	•	•	•		
Saw Guide Oil Additives																	
SGP-567	1.50%	•	•			•	•	•	•	•	•	•	•	•	•		•
SGP-571	3.00%	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•

Compatible = clear and bright solution at treat (min. 5wt%) after freeze/thaw

Formulate with FPI

- Biobased presents new raw materials, new strategies
  - Use Functional to accelerate your entry into the biobased market

- Experience in formulating biobased:
  - Bar & chain
  - Rock drill
  - Hydraulic fluids
  - Oven chain
  - Wire rope
  - Greases (w/ soap)
  - Polymers greases – rail/curve grease, wire rope (polymer + oil)

  - w/ certifications
    - Ecolabel/VGP/EAL lubricants
    - H1 biobased lubricants

Bar and Chain

- Very simple, lowest cost to compete with petroleum bar and chain:

		TACKY		VERY TACKY		EXCEPTIONALLY TACKY	
Component	**% Bio**	**ISO 100**	**ISO 150**	**ISO 100**	**ISO 150**	**ISO 100**	**ISO 150**
Canola Oil	100	84.5	80.5	85	80	75	67
Functional V-515	90	8	13	7	11	0	0
Functional V-584	95	7.5	6.5	8	9	25	33
Pour Point (D97)		-24C	-24C	-24C	-24C	-24C	-24C
String Length (DS)		50 - 65	50 - 65	65 - 80	65 - 80	80 - 100	80 - 100
% Biobased		98.8	98.4	98.9	98.5	98.8	98.4

- Options:
  - Add 0.5wt% **PD-585** for -33°C pour point
  - Add 0.2wt% **CI-426** for D665A turbine oil rust pass
  - Add 2.0wt% **CI-526EP** for anti-wear / EP
  - Replace **V-515** with **V-508M** for Ecolabel

Rock Drill

- Functional RD-535 (5wt%) – emulsifying RD package

		HEAVY DUTY FULL BIO		
Component	**% Bio**	**ISO 100**	**ISO 150**	**ISO 220**
Canola	100	82	77	72
Functional V-515	90	12	17	22
Functional RD-535	40	5	5	5
Functional PD-585	N/A	0.5	0.5	0.5
Viscosity Index		248	251	261
4-Ball EP Weld Load (D2783)		250 kgf	250 kgf	250 kgf
Load Wear Index		53.4	54.1	50.6
Timken OK Load (D2782)		70 lb	70 lb	70 lb
Falex Block and V (D3233B)		4500 lb	4530 lb	4550 lb
4-Ball Wear, 20 kgf (D4172)		0.3	0.29	0.33
Pour Point (D97)		-33C	-33C	-33C
%Biobased		95.8	95.3	94.8

- Options:
  - **Functional RD-535CP** (6wt%) – demulsifying RD package

Non-EAL Hydraulics

- Non-EAL biobased hydraulics in veg oil and synthetic ester
  - Veg and synthetic formulas combined to produce semi-synthetic grades

ISO 32/46 Veg / Semi-Syn / Synthetic Hydraulic Fluids

Formula by wt%	**ISO 32 VEG ECON.** F-336-16F	**ISO 32 VEG** F-336-15B	**ISO 32 SEMISYN A** F-336-16A	**ISO 32 SEMISYN B** F-336-16C	**ISO 32 SYN** F-336-15D	**ISO 46 VEG** F-336-15E	**ISO 46 SEMISYN** F-336-16B
High Oleic Soy Oil	89.7	78.5	39.25	11.78	0	95.5	47.75
Diisodecyl Adipate	0	18.5	54	78.85	89.5	0	43
Methyl Ester	7.7	0	0	0	0	0	0
Functional V-521	0	0	4	6.8	8	1.5	6.5
Functional PD-585	0.5	0.5	0.25	0.08	0	0.5	0.25
Functional HF-580	2.5	2.5	2.5	2.5	2.5	2.5	2.5
KV40 (D445)	32.57	33.72	34.41	33.63	33.66	47.55	47.33
KV100 (D445)	7.59	7.38	7.68	7.89	8	9.86	10.44
VI (D2270)	214	188	202	219	223	200	218
Pour Point (D97)	-27C	-27C	-42C	-54C	-54C	-27C	-33C
% Biobased	97.4%	95.2%	91.2%	88.5%	87.3%	96.8%	91.9%

EAL Hydraulics

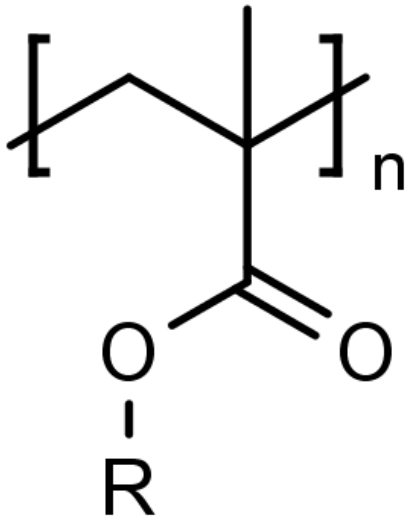
- V-508M in vegetable oil w/ HF-590
  - Modest pour point of vegetable oils compliments modest V-508 low T

- V-521 in synthetic ester w/ HF-590
  - Best use of low temperature VM and low temperature ester

Formula by wt%	**ISO 32 EAL VEG** F-339-25-32	**ISO 46 EAL VEG** F-339-25-46	**ISO 68 EAL VEG** F-339-25-68	**ISO 32 EAL SYN** F-339-40-32	**ISO 46 EAL SYN** F-339-40-46	**ISO 68 EAL SYN** F-339-40-68
Canola Oil	94.6	91.8	86.7			
Functional V-508M	0	2.8	7.9			
Functional PD-585						
Synative ES DITA				94.6	89.6	84.6
Functional V-521					5	10
Functional HF-590	5.4	5.4	5.4	5.4	5.4	2.5
KV40 (D445)	36.0	45.7	72.1	28.8	47.4	66.7
KV100 (D445)	8.35	10.4	15.2	5.5	9.0	13.7
VI (D2270)	220	226	224	137	174	214
Pour Point (D97)	-30C	-27C	-24C	-60C	-60C	-60C
% Biobased	94.6%	94.1%	93.1%	85.1%	84.8%	84.5%

Biodegradable Gear

- Polymethacrylate viscosity modifier
  - **Functional MG-1000** (15 SSI by KRL)
  - **Functional MG-3000** (20 SSI by KRL)
  - **Functional MH-2000** (35 SSI by KRL)



- **Functional GA-614** gear package (metal-free, S/P)
  - 1.5wt% = 250 kgf EP
  - 3.0wt% = 315 kgf EP
  - 5.0wt% = 620 kgf EP

- Base fluid is biobased ester or biodegradable PAO
  - PAO2 = 75-90%; PAO4 = 50-70%

- Functional can design for: visc grade, VI, shear, % bio, pour point

Summary

- Functional Products tailors products and services for specialty markets

- Biobased
  - Environmentally friendly lubricant additives
  - Biobased vs. biodegradable
  - Sample formulations for biobased lubricants