Emerging Opportunities for Natural Oil Based Chemicals

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Technical Learnings of Oleochemicals for Make Benefit Glorious Provinces of Western Canada

Why do we need to discuss oilseeds?

- Conventional View is Positive:
  - Low cost reserves of crude oil are expected to significantly decline during 21st century
  - Petroleum based economy is anticipated to be higher cost vs. bioeconomy
  - While biomass (plant fibre) based chemicals are the likely ultimate target, vegetable oil based chemicals are viewed to have ongoing opportunities
- But, there are challenges.

Challenges to Growth in Oleochemicals

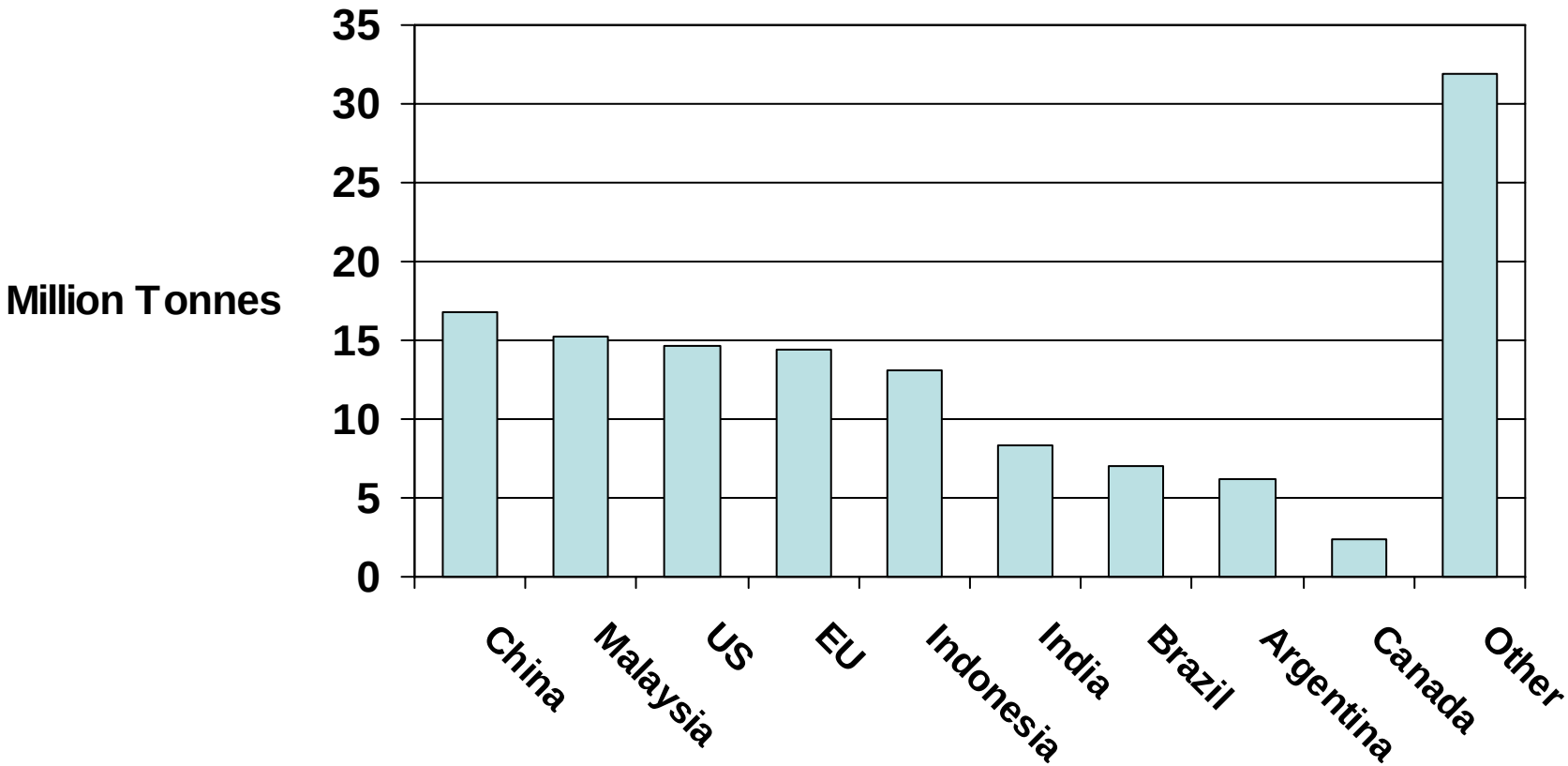
- Will there really be a cost advantage?
  - Increasing fuel prices will transfer to higher prices for biofuels, including fatty acid methyl esters (FAME)
- How can traditional chemicals be displaced?
  - Petrochemicals are highly integrated with the huge industrial growth of the 20th century
- There are issues of supply (quality and quantity)
  - Current fats and oils production is less than 15% of petrochemical production
- Ongoing fluctuations in Fats and Oils business
  - M&A's
  - New volumes from Asia and China
  - Surplus quantities of glyerol
  - Biodiesel demand for oils

A Quick Market Review

- Fats and Oils consumption, production
- Major oleochemical producers
- Chemistries and applications
- New technologies
  - Oil production
  - Fatty acids
  - Bio-lubricants

Global Fats and Oil Production

Total Global Production: 130 million tonnes



The Fats and Oils Market

- Approximately 30% of North America fats and oils are consumed for non-food applications
  - 5 million tonnes
  - 1.2 million tonnes as fatty acid based chemicals
- US vegetable oil production is app 8 M tonnes, most of which is soy
- Soy + Palm = 50% of global production
- Market demand for chemical uses have been normally tied to economic activity (projected at 2% annual growth)
- Most significant growth in new demand is for biodiesel
  - has lead to considerable realignments within industry

The Fats and Oils Market

- New production of fatty alcohols – 600,000 to 850,000 tonnes - is expected for 2007
- New partnerships, JV's, acquisitions
  - Sasol / Wilmar
  - P&G / Feixang Chemicals
  - Cognis / Thai Ethoxylate
  - V V F acquires 2 North American facilities for personal care products
  - Oleon buys Akzo Nobel
  - Croda buys Uniqema
  - Kuala Lumpur Kepong buys W. Kolb Holding
- Glycerol prices drop 20%, with some recovery expected due to new demand (for refined glycerol)

Major Oleochemical Producers

- ADM
  - linseed and soy based inks, coatings, adhesives, wax, personal care products
- Cargill
  - base oils, lubricants, polyols, esters, fatty acids, wax
- SE Asian Companies
  - Kuala Lumpur Kepong, OIO Corp., Wilmar
- Croda (Uniqema)
  - full line of oil products and oleochemicals
- Chemtura
  - wide range of fatty acid based chemicals, synthetic lubricants

Major Oleochemical Producers

- Cognis
  - Wide range of products, “ozone chemicals”, oilfield chemicals
- P&G Chemicals
  - Fatty alcohols, acids, amines, esters
- Akzo Nobel (now Oleon)
  - Fatty amine surfactants, full range of fatty acids
- Arkema
  - Epoxidized soy and linseed oil
- Kolb Holdings
  - Fatty acid and alcohol ethoxylates
- V V F
  - Fatty acids and alcohols

Primary Industrial Vegetable Oils

- Linseed, Rape, Soy, Castor, Wood (tall), Sunflower, Safflower, Peanut
- Products sold as
  - Crude
  - Refined
  - Boiled
  - Oxidized (blown oils)
  - Polymerized (stand oils)
  - Emulsifiable

Industrial Uses of Natural Oils

- As an oil
  - binder/crosslinker
  - lubricants, greases, cosmetics, plasticizers
- As a feedstock for fuel and solvents
  - fatty acid esters (methyl, ethyl, propyl)
- As a feedstock for chemical production
  - glycerol
  - higher molecular weight esters
  - fatty acids, amides, alcohols, amines
  - Dimers and other chemical derivatives

Primary Markets

- Neat Oils
  - Coatings, sealants, inks
  - Lubricants and greases
  - Personal care products
- Fatty Acids Production (C_{14} – C_{22})
  - Amines -> surfactants, cleaners, biocides
  - Alcohols -> sulfate and ethoxylate detergents, emulsifiers
  - Dimer Acids -> crosslinkers, polyamides, corrosion inhibitors
  - Amides -> surfactants
  - Esters -> plasticizers, emollients

Overall Market Assessment

- Oleochemical market is
  - well established
  - mature technologies
  - lots of integration and infrastructure

Overall Market Assessment

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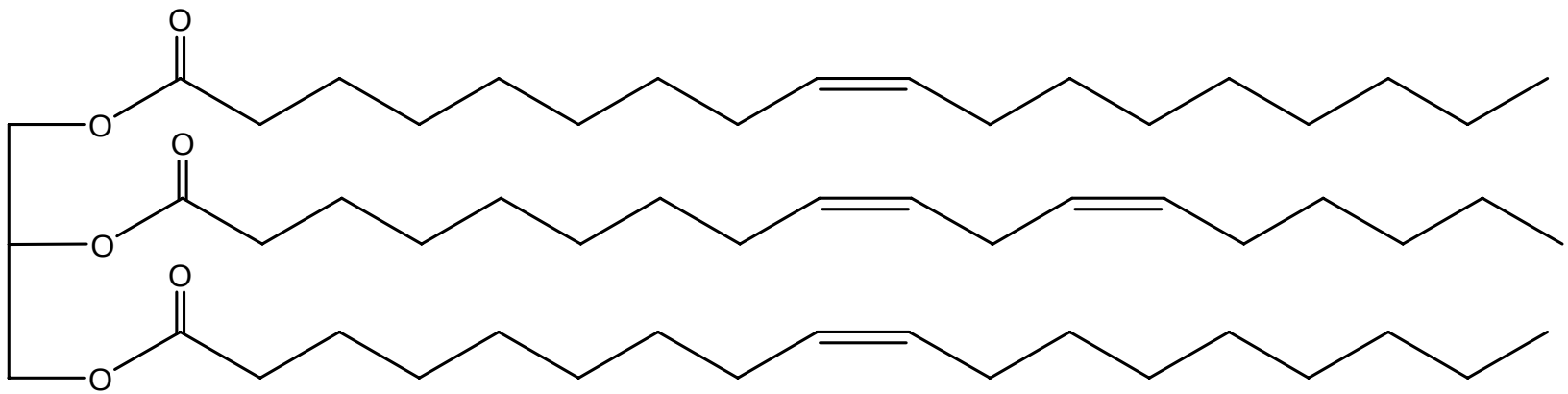
  - mature technologies
  - lots of integration and infrastructure
- What to do?

Where are the Opportunities?

- Develop applications
  - Biolubricants
  - New polymer and coatings technology
- “Grow” new chemicals
  - Specific fatty acid production
  - Specific degrees of unsaturation
  - Genetically engineer new fatty acid production
- Low cost chemical processing technology
  - Functionalized or modified triglycerides
  - Catalyst technology of production of low molecular weight chemicals
- Glycerol Utilization
  - By-product of biodiesel production
  - A versatile industrial polyol

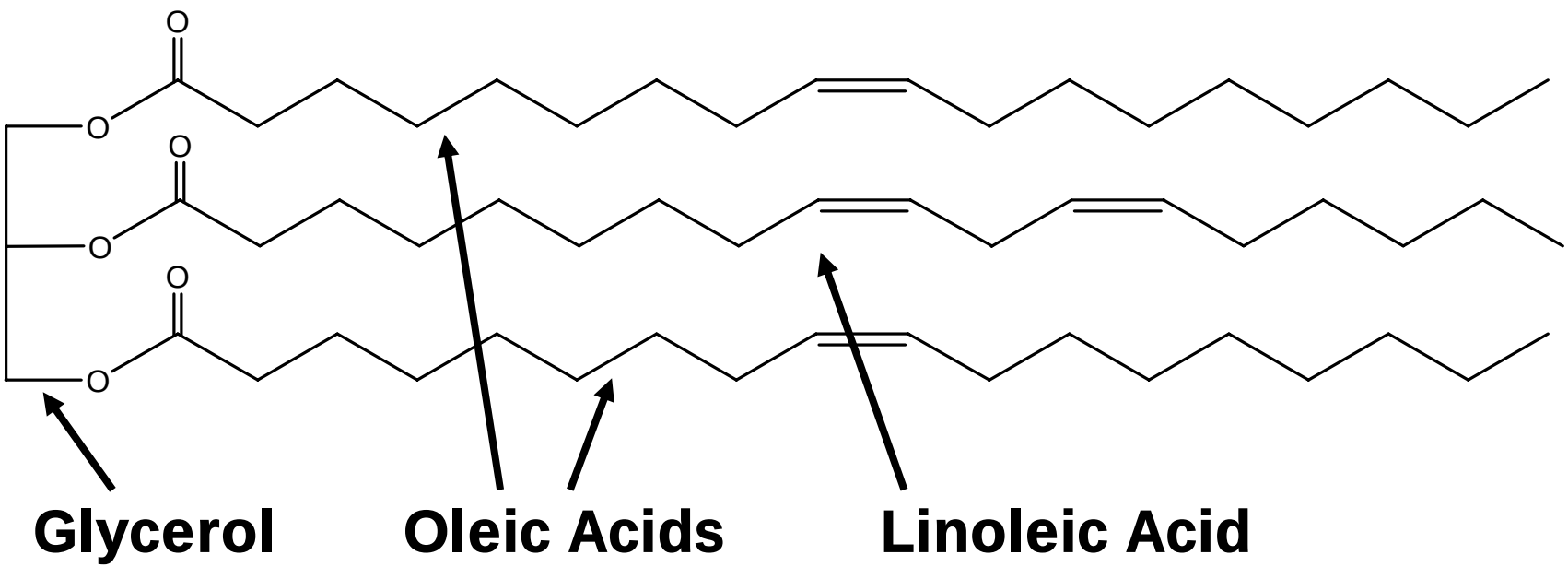
Chemistry Lesson

- What are the chemicals in oils
- Examples of modifications



Natural Esters (triglyceride)

A “Canola Oil Molecule”



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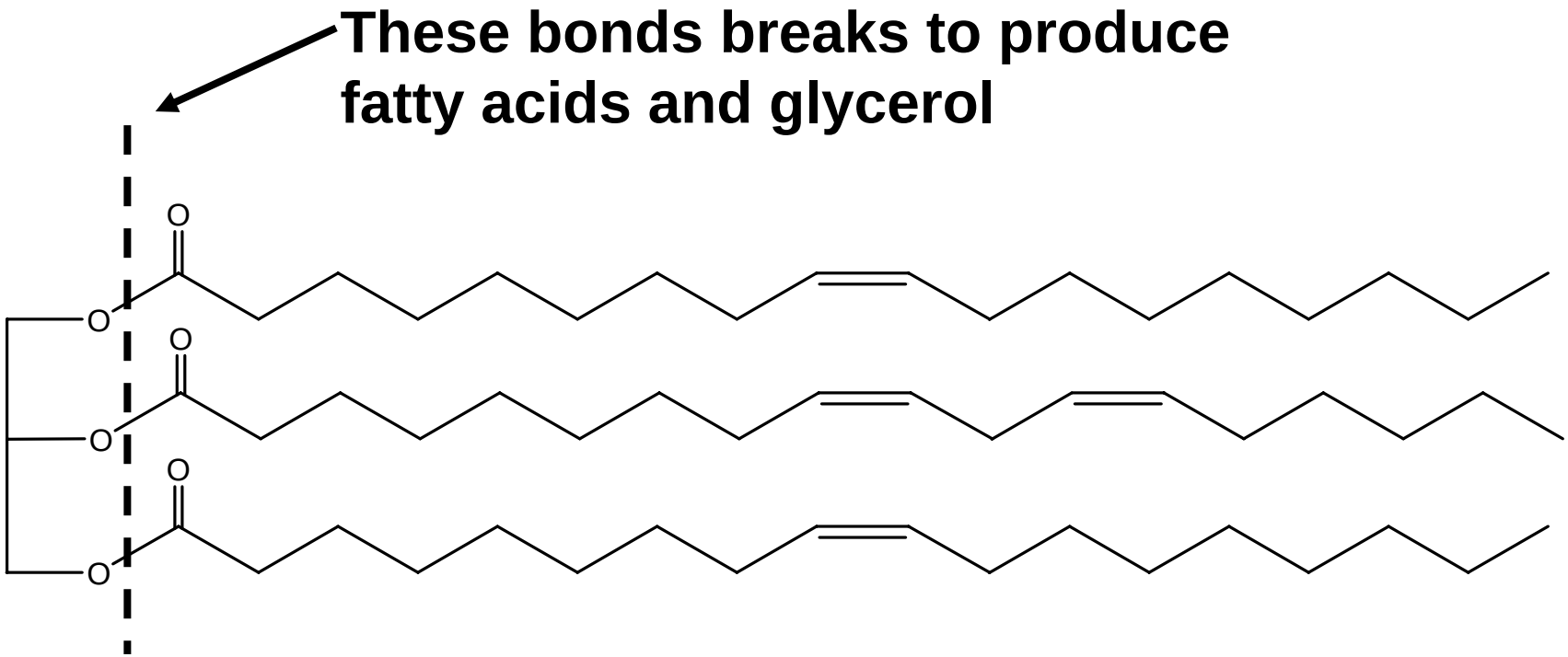

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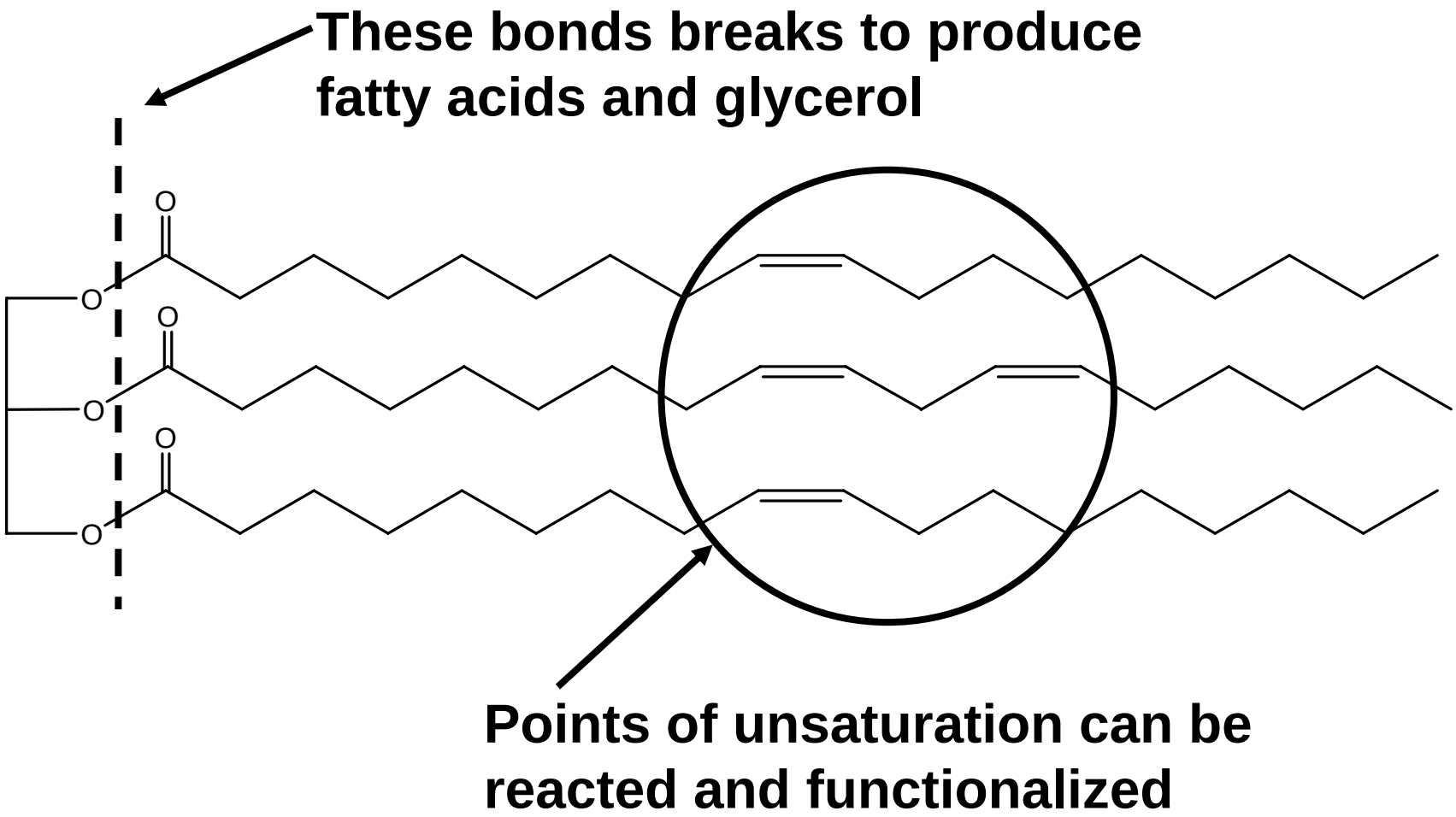
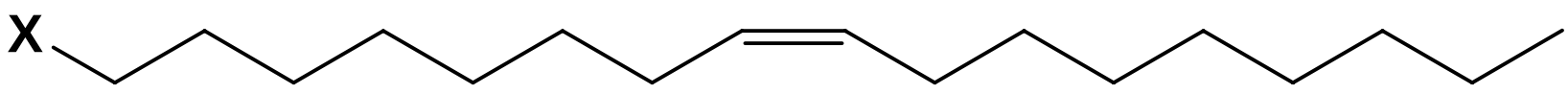
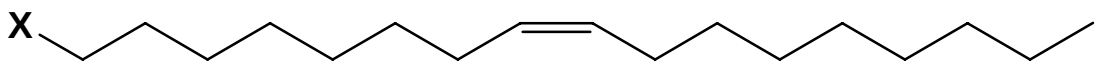


Fatty Acid Derivatives



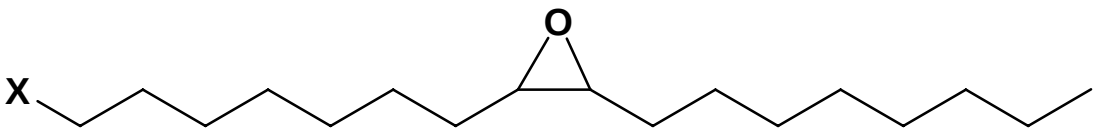
X =		
	CO_2H	acid
	$CONH_2$	amide
	COOR	ester
	CH_2OH	alcohol
	CH_2NH_2	amine
	$CH_2NR_3^+$	“quat”

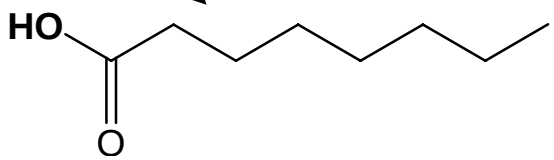
Other Chemical Treatments



Epoxidation

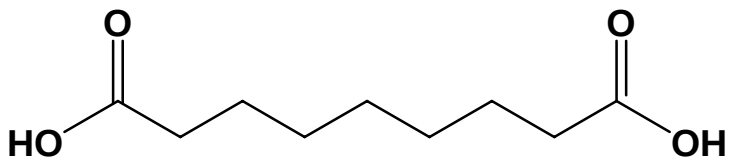
1. Ozonolysis
2. Oxidation





Pelargonic Acid

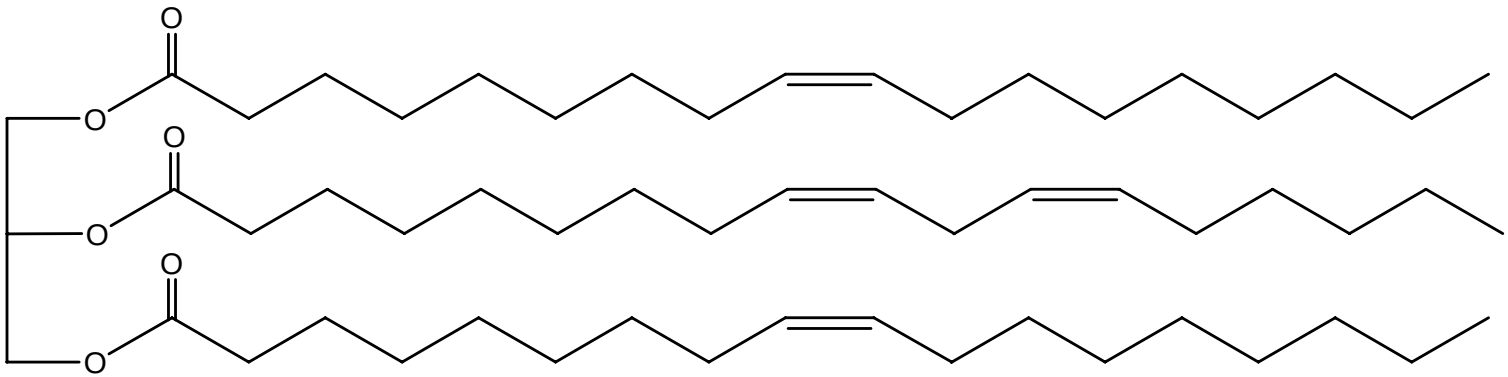
+



Azelaic Acid

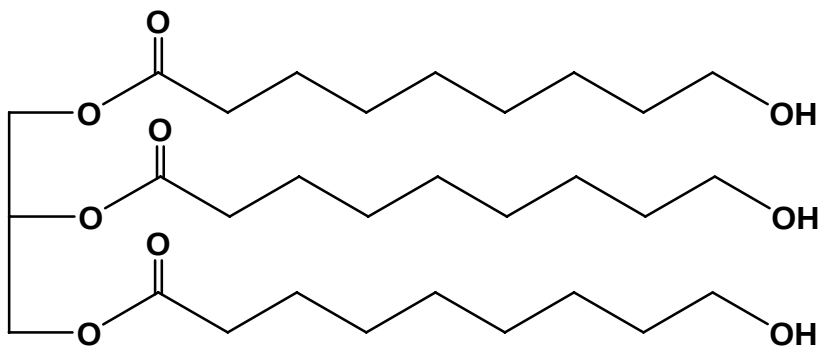
Further reactions at the epoxide site

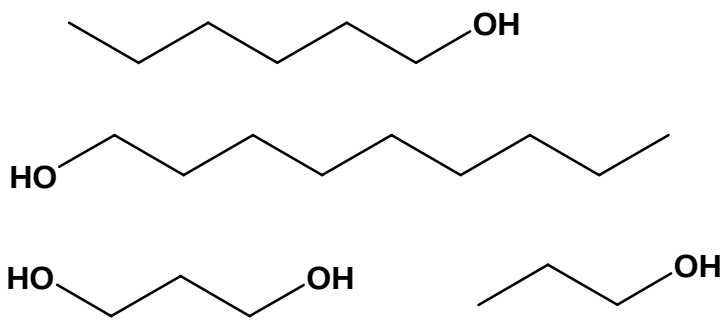
Other Chemical Treatments



1. **Ozonolysis**
2. **Hydrogenation**

Narine et al
U of Alberta





Fatty Acid Sources

	C_{12}	C_{14}	C_{16}	C_{18}	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	C_{20}	Other
Tall Oil					42	35			23
Palm			44		40	10			
Palm Kernel	49	16	9		15	2			
Linseed			6		17	14	60		
Soybean			11		22	53	8		
Canola/LEAR			4		60	26	10		
Castor			1		3	4			90
Tallow		6	26	31	31	2			
Corn			13		31	52			
Sesame			9		38	45			
Sunflower			6		18	69			
Cottonseed			24		19	53			

Primary Uses of Fatty Acids

- Personal Care Products
  - Emollients, emulsifiers, surfactants
  - Laurate esters, glycerol monostearate, ricinoleates
- Lubricants, Oilfield Chemicals, Additives
  - Synthetic polyol, esters, isopropyl oleate, tranesterified derivatives, diacid corrosion inhibitors
- Polyamides (from tall oil dimer acids)
- Plastic Additives
  - Fatty acid esters
- Household and Industrial Cleaners
  - Fatty amines, amides, quats, alcohol ethoxlates, ethanolamines
- Coatings, Adhesives, Inks, Wax, Fabric Softeners, Emulsifiers (mining and agricultural)

Fatty Acid Supply/Demand

Million Tonnes

	2000		2005		2010	
	Capacity	**Demand**	**Capacity**	**Demand**	**Capacity**	**Demand**
Europe	1.5	1.3	1.5	1.7	1.5	2
North America	1.1	0.9	1.1	0.9	1.1	0.92
Asia/Other	2.4	1.68	3.7	2.6	5	3.5

4% annual growth in demand over next 5 years

A Brief Comment on Biodiesel

- Canola, LEAR, and Soy are well accepted as feed stock for high quality diesel fuel
- Large increases of SE Asian palm oil are anticipated to stream into biodiesel demand
- Fuel properties a significant issue in northern climates
- Fuel properties are directly related to fatty acid profile

Properties of Fatty Acid Methyl Esters

Ester	Density @15.5°C	Viscosity cSt @ 40°C	Cetane No.	Heating Value (MJ/kg)	Melting Point (°C)
Palmitate	0.867	4.37	74	39.4	30.6
Stearate	0.867	5.79	75	40.1	39.1
Oleate	0.878	4.47	55	39.9	-19.8
Linoleate	0.890	3.68	33	39.7	-35.0

BioBased Lubricants

- Global lubricants market is nearly 40 million tonnes
- Market penetration of biobased oils has been slow
  - Only 4% of German market
- Performance of neat vegetable oils is limited
  - Oxidative stability, low temperature fluidity, hydrolytic stability and material compatibility
- Opportunity is likely related to chemically modified vegetable oils that meet renewables content legislation
  - 50% renewable content to meet EU Ecolabel
  - 44% renewable content in hydraulic fluids to meet US 2002 Farm Bill guidelines
  - Cognis has developed saturated branched ester fluids for use in the oilfield

Chemistry of Vegetable Oils

- Long chain fatty acids contribute to
  - High viscosity index (good temperature response)
  - Poor low temperature properties (high pour points)
- Saturated fatty acids have better stability, but poorer low temperature properties
- Unsaturation contributes to poor thermal and oxidation stability
  - Hydrogenation can improve stability, but adversely affects low temperature properties

Applications of Vegetable Oil Lubricants

- Common situational usage
  - Used based on legislation and/or corporate environmental policy
  - Fresh water management (pumps)
  - Environmentally sensitive areas (wetlands, near watershed)
  - Forestry
  - High loss applications
- Common applications are
  - Hydraulic oils
  - Chain bar oils
  - Metal working fluids
  - Industrial gear oils
  - Two-Stroke motor oils
  - Wire rope Lubricant
  - Greases

Lowest Cost Vegetable Base Oils

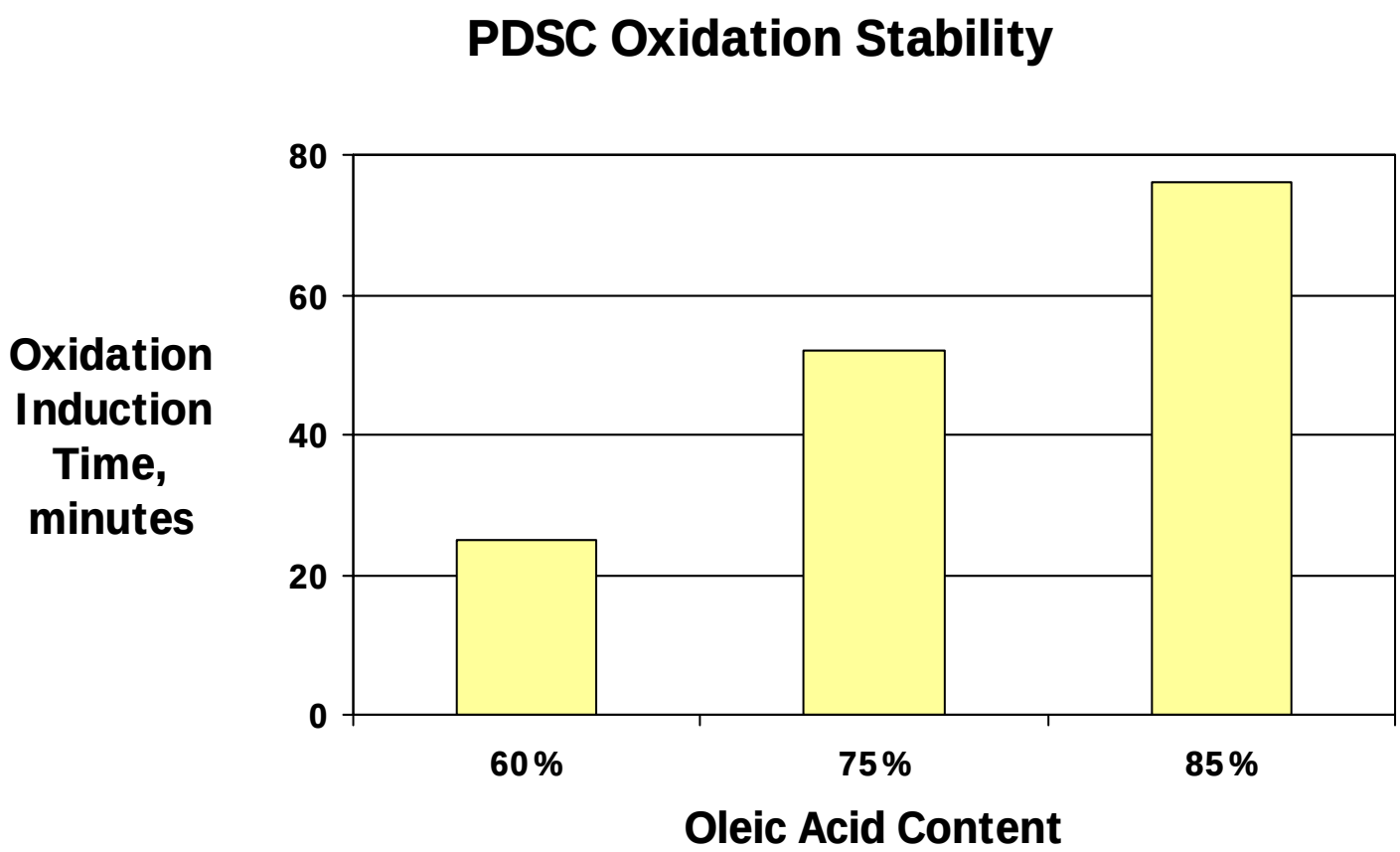
- Soy and canola (and low erucic rape) oils most common
- Sunflower, palm, cottonseed oils also used
- Castor oil used as additive (but higher priced)
- Newer plant strains can have elevated oleic acid levels
  - driven by edible oil market health concerns (low saturated fats)
  - also provides performance benefit for lubes

Base Oil Comparisons*

	Mineral Oil	RBD Vegetable Oil
Flash Pt.	200°C	300°C
Pour Pt.	-22°C	-15°C
Viscosity Index	95	200
Lubricity	low	high
Current Price	0.86 $/L (crude: 0.43 $/L)	0.78 $/L (crude: 0.66 $/L)

* typical values

High Oleic Oils



Data source: Cargill

Recent Innovations

- Vegetable oils are being produced specific fatty acid content
  - High oleic content, hydroxy fatty acids
- Vegetable oils are used as blends with synthetic ester
  - Reduces product cost while still providing good performance
  - Meets potential corporate guidelines for minimum “green” content
- New chemical processing
  - Natural triglyceride can be “transesterified” to form a new esters of higher quality
  - Estolides from oils with hydroxy fatty acids
  - Branched esters

Outlook for Biolubricants

- Near term growth likely related to legislated renewables content (US and EU)
- Canola is well positioned as a lubricant base oil
- Performance improvements are required for wider use
- Original equipment manufacturers need to be convinced
  - John Deere, Caterpillar have biobased hydraulics in their own product lines, but they are rarely used in Canada

Outlook for Fats and Oils

- Product cost still an issue
  - Customers are all for “green” products and chemicals, as long as they are not more money!
- Biodiesel demand is expected to drive up the market value of vegetable oil feed stock
- Ongoing R&D efforts should begin to pay off
- GM industrial crops leading to tailored fatty acid profiles need defined markets and should have lower processing costs
- Higher than average growth may be expected in sectors where new biobased chemicals are accepted
  - Dependent on relative pricing and availability of petrochemicals
- What volume non-food fats and oils can be produced without significant affect on food prices?

Unique Fatty Acid Profiles Have Value

- Linseed/Flax
  - High in polyunsaturated fatty acids
- Castor, Lesquerella
  - Hydroxy fatty acids that have better functionality for crosslinking
- HEAR, Crambe
  - Erucamide is the best plastic film lubricant
- Canola
  - Low saturated, low PUFA
- Tung, Calendula
  - More reactive conjugated polyunsaturated fatty acids
- Camelina
  - High PUFA, plus 12% Eicosenoic acid (20:1)

Technologies for Biobased Chemicals

- Biobased plastics are entering the market
- Chemically derived organics as alternatives to petrochemical products
  - Alcohols and esters
  - Bioplastics
  - Ozonolysis chemicals could include a range of diacids, alcohols, and polyols
  - Epoxide derivatives
- End game ?
  - Low cost catalytic processing for high volume chemical production

What Needs to be Addressed

- Versatility and consistency of vegetable oils that can match what is available synthetically
- Processing costs
- Facilitation of changes in chemical sources and logistics
- A relatively low level of chemical manufacturing infrastructure in Western Canada
- Integrated approach with chemicals market
  - New technology needs buy-in from marketer and users


Thank you !