Emerging Opportunities for Natural Oil Based Chemicals

Dr. Ray Bergstra
MTN Consulting Associates

Plant Bio-Industrial Workshop
Saskatoon, Saskatchewan, Canada
February 27, 2007
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 glycerol
  - 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

Million Tonnes

- China
- Malaysia
- US
- EU
- Indonesia
- India
- Brazil
- Argentina
- Canada
- Other
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\textsubscript{14} – C\textsubscript{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

- Oleochemical market is
  - well established
  - 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”

Glycerol  Oleic Acids  Linoleic Acid
Natural Esters (triglyceride)

These bonds break to produce fatty acids and glycerol
Natural Esters (triglyceride)

These bonds breaks to produce fatty acids and glycerol

Points of unsaturation can be reacted and functionalized
Fatty Acid Derivatives

\[ X = \text{CO}_2\text{H} \quad \text{acid} \]
\[ \text{CONH}_2 \quad \text{amide} \]
\[ \text{COOR} \quad \text{ester} \]
\[ \text{CH}_2\text{OH} \quad \text{alcohol} \]
\[ \text{CH}_2\text{NH}_2 \quad \text{amine} \]
\[ \text{CH}_2\text{NR}_3^+ \quad \text{“quat”} \]
Other Chemical Treatments

Epoxidation

Further reactions at the epoxide site

1. Ozonolysis
2. Oxidation

Pelargonic Acid

Azelaic Acid
Other Chemical Treatments

1. Ozonolysis
2. Hydrogenation

Narine et al
U of Alberta
## Fatty Acid Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>C12</th>
<th>C14</th>
<th>C16</th>
<th>C18</th>
<th>C18:1</th>
<th>C18:2</th>
<th>C18:3</th>
<th>C20</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tall Oil</td>
<td></td>
<td></td>
<td></td>
<td>42</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>Palm</td>
<td></td>
<td>44</td>
<td></td>
<td>40</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palm Kernel</td>
<td>49</td>
<td>16</td>
<td>9</td>
<td>15</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linseed</td>
<td>6</td>
<td></td>
<td>17</td>
<td>14</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td>11</td>
<td>22</td>
<td></td>
<td>53</td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canola/LEAR</td>
<td>4</td>
<td></td>
<td>60</td>
<td>26</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Castor</td>
<td>1</td>
<td></td>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90</td>
</tr>
<tr>
<td>Tallow</td>
<td>6</td>
<td>26</td>
<td>31</td>
<td>31</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>13</td>
<td></td>
<td>31</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sesame</td>
<td>9</td>
<td></td>
<td>38</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunflower</td>
<td>6</td>
<td></td>
<td>18</td>
<td>69</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cottonseed</td>
<td>24</td>
<td></td>
<td>19</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>1.5</td>
<td>1.3</td>
<td>1.5</td>
<td>1.7</td>
<td>1.5</td>
<td>2</td>
</tr>
<tr>
<td>North America</td>
<td>1.1</td>
<td>0.9</td>
<td>1.1</td>
<td>0.9</td>
<td>1.1</td>
<td>0.92</td>
</tr>
<tr>
<td>Asia/Other</td>
<td>2.4</td>
<td>1.68</td>
<td>3.7</td>
<td>2.6</td>
<td>5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

4% annual growth in demand over next 5 years

ICIS Chemical Business
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

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

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

* typical values
High Oleic Oils

PDSC Oxidation Stability

Oxidation Induction Time, minutes

Oleic Acid Content

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 !