SOYBASED COATINGS
WHY YOU SHOULD CONSIDER SOYBEAN OIL FOR TOMORROW’S COATINGS

Coatings Trends and Technologies 2019

Kris Weigal, Biobased Business Development-Senior Consultant
Omni Tech International, Ltd.
Outline

• US Soybean Board
• Global Supply and Sustainability
• Soybean Oil
  • Composition and Derivatives
• Soy in Coatings
  • Why Soy?
  • Applications
• Success Stories
UNITED SOYBEAN BOARD

• Promoting and communicating sustainability of U.S. soy farming

• USB administers soybean checkoff activities focusing on research and market development and expansion

• Checkoff contributions of 0.5% of the market price per bushel sold each season

• In 2018 the checkoff program collected $103M for investment in oil, meal, seed, and sustainability

• By building demand both at home and abroad, the soybean checkoff helps ensure a strong and profitable future for U.S. soybean farmers
### Developing New Industrial Uses for Soybean Products

<table>
<thead>
<tr>
<th>Paint</th>
<th>Roads</th>
<th>Farm Equipment</th>
<th>Cleaners</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Paint" /></td>
<td><img src="image2.png" alt="Roads" /></td>
<td><img src="image3.png" alt="Farm Equipment" /></td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flooring</th>
<th>Tires</th>
<th>Automotive</th>
<th>Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5.png" alt="Flooring" /></td>
<td><img src="image6.png" alt="Tires" /></td>
<td><img src="image7.png" alt="Automotive" /></td>
<td><img src="image8.png" alt="Parts" /></td>
</tr>
</tbody>
</table>
A GLOBAL PRODUCT

Global Soybean Production 2018

- United States: 34%
- Brazil: 33%
- Argentina: 15%
- China: 4%
- India: 3%
- Other: 6%
- Paraguay: 2%
- Canada: 2%

Sources:
- SoyStats
- USDA

Global Exported 2018

<table>
<thead>
<tr>
<th></th>
<th>Production</th>
<th>Export</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>4,545</td>
<td>1,875</td>
<td>41%</td>
</tr>
<tr>
<td>Brazil</td>
<td>4,299</td>
<td>2,921</td>
<td>68%</td>
</tr>
<tr>
<td>Argentina</td>
<td>2,021</td>
<td>231</td>
<td>11%</td>
</tr>
<tr>
<td>Other</td>
<td>794</td>
<td>244</td>
<td>31%</td>
</tr>
<tr>
<td>Paraguay</td>
<td>349</td>
<td>206</td>
<td>59%</td>
</tr>
<tr>
<td>Canada</td>
<td>268</td>
<td>195</td>
<td>73%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>12,276</td>
<td>5,672</td>
<td>46%</td>
</tr>
</tbody>
</table>

M Bushels

Sources: SoyStats
USDA
SOYBEAN DECONSTRUCTION

Typical yield per bushel

Meal = 44.4 lbs.
Oil = 11.5 lbs.
Hulls = 3.6 lbs.
Forecast for the next five years
U.S. SOY SUSTAINABLE STORY

U.S. Soy Sustainability Assurance Protocol (SSAP)

• Third-party audited certification
  • >95% of U.S. soybean farmers participate

Focuses on four sustainability directives

• Biodiversity
• Conservation
• Public labor, health and welfare
• Continuous improvement in technology and cultural practices
SUSTAINABILITY PROGRESS

Since 1980 – U.S. soybean farmers have produced more with less...

Farmers have increased their yields by 55% on roughly the same amount of land through conservation practices.

Decreases achieved in
- Carbon Emissions
- Energy/Fuel Use
- Greenhouse Gas
- Soil Erosion

Source: USSEC
CHEMISTRY OF SOY FOR COATINGS
Fatty Acid Building Blocks

- **Linoleic acid**
  - \(C_{18}H_{32}O_2\)
  - 25%
  - \(C_{18}:2\)

- **Oleic acid**
  - \(C_{18}H_{34}O_2\)
  - 58%
  - \(C_{18}:1\)

- **\(\gamma\)-Linolenic acid**
  - \(C_{18}H_{36}O_3\)
  - 5%
  - \(C_{18}:3\)

- **Stearic acid**
  - \(C_{18}H_{36}O_2\)
  - 8%
  - \(C_{18}:0\)

- **Palmitic acid**
  - \(C_{16}H_{32}O_2\)
  - 4%
  - \(C_{16}:0\)

Fatty Acids

- 58%
- 5%
- 4%
- 8%
WHY SOY IN COATINGS

- Hydrophobic nature
- Double bonds - crosslinking
  - Film hardness
  - Durability
  - Impact resistance
- C18 carbons chains
  - Flexibility
  - Molecular weight
- Benefits
  - Resistance to water, polar solvents, acids/bases
  - Dirt and stain resistance
  - Adhesion
SOY IN COATINGS HISTORY

- Soy-Based Reactive Diluents
- Soy-Based Functional Additives
- Soy-Modified Latex
- Direct Drop-In

Solvent Soy Alkyds

- High Solids Alkyd
- Alkyd Emulsions
- Acrylic Alkyd Hybrids
- Water Based Alkyds

Soy-Modified Polyurethane Dispersions
# BASIC SOY OIL BUILDING BLOCKS

## Commercially Available

<table>
<thead>
<tr>
<th>Soybean Oil (Triglyceride)</th>
<th>Soy Methyl Soyate</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Soybean Oil (Triglyceride)" /></td>
<td><img src="image2" alt="Soy Methyl Soyate" /></td>
</tr>
</tbody>
</table>

- **Diols ➔ PUDs & Reactive Diluents**
- **Polyols ➔ 2K Polyurethane & Melamine**
- **Acrylated Polyols ➔ UV Chemistry**
- **Silanes ➔ Waterborne & UV**
## FUTURE SOY OIL BUILDING BLOCKS

<table>
<thead>
<tr>
<th>Compositi</th>
<th>Name</th>
<th>Formula</th>
<th>MW</th>
<th>Commodity Soy Oil</th>
<th>High Oleic Soybean Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>C16:0</td>
<td>Palmitic Acid</td>
<td>$C_{16}H_{32}O_{2}$</td>
<td>256.4</td>
<td>11.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>C18:0</td>
<td>Stearic Acid</td>
<td>$C_{18}H_{36}O_{2}$</td>
<td>284.5</td>
<td>4.0%</td>
<td>3.5%</td>
</tr>
<tr>
<td>C18:1</td>
<td>Oleic Acid</td>
<td>$C_{18}H_{34}O_{2}$</td>
<td>282.5</td>
<td>23.0%</td>
<td>75.5%</td>
</tr>
<tr>
<td>C18:2</td>
<td>Linoleic Acid</td>
<td>$C_{18}H_{32}O_{2}$</td>
<td>280.5</td>
<td>54.0%</td>
<td>12.5%</td>
</tr>
<tr>
<td>C18:3</td>
<td>Linolenic Acid</td>
<td>$C_{18}H_{30}O_{2}$</td>
<td>278.4</td>
<td>8.0%</td>
<td>3.5%</td>
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</tbody>
</table>

Now

Emerging
SUCCESS STORIES
ARKEMA

Soy-Based, Zero-VOC Coalescent for Waterborne Coatings

• USB Project #: 1940-362-0715-E
• First year of funding
VIKOFLEX® 2200: SOY-BASED COALESCENT

• ZERO VOC content and >85% renewable content
• Low color and viscosity
• Excellent coalescent efficiency
• Similar performance to leading commercial low and zero VOC coalescents
• Broad formulation latitude for architectural paints
• Manufactured domestically in eco-friendly, ISO-9001 registered plant with zero waste water discharge and emissions

Paint performance comparable to leading zero-VOC coalescent

• Evaluated in 4 formulations:
  - Semi-gloss and flat acrylic (Encor 636) and vinyl acrylic (Encor 309) paints
• Confirmed in 2 customer formulations relative to benchmark
## PERFORMANCE SUMMARY

<table>
<thead>
<tr>
<th>Formulation</th>
<th>LTC</th>
<th>Konig hardness</th>
<th>KU</th>
<th>Scrub</th>
<th>Heat Age</th>
<th>QUV-A</th>
<th>Tint strength</th>
<th>Washability (hydrophobic)</th>
<th>Washability (hydrophilic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encor 309 Flat</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Encor 309 Semi-gloss</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>+</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>-</td>
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<th>Tint strength</th>
<th>Washability (hydrophobic)</th>
<th>Washability (hydrophilic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encor 636 Flat</td>
<td>+</td>
<td>+</td>
<td>=</td>
<td>+</td>
<td>=</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Encor 636 Semi-gloss</td>
<td>+</td>
<td>=</td>
<td>=</td>
<td>+</td>
<td>=</td>
<td>+</td>
<td>=</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formulation</th>
<th>LTC</th>
<th>Hiding</th>
<th>Gloss</th>
<th>Tint Strength</th>
<th>Scrub Resistance</th>
<th>Washability</th>
<th>MPI Cleansability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vikoflex 2200</td>
<td>+</td>
<td>+</td>
<td>=</td>
<td>+</td>
<td>+</td>
<td>=</td>
<td>slight +</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Formulation</th>
<th>LTC</th>
<th>Mudcracking</th>
<th>Tint Strength</th>
<th>Scrub Resistance</th>
<th>Washability Hydrophilic</th>
<th>Washability Hydrophobic</th>
<th>Wet Adhesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vikoflex 2200</td>
<td>=</td>
<td>+</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
Conclusions

• High Soybean Oil content
• Performance equal to better to competitive products
• Commercialization is underway
**RUST-OLEUM**

New platform of interior/exterior wood stains and finishes based on soy polyurethane dispersions

- USB Project #: 1540-612-6263
- Four years of funding

**Soy Based Alkyd Technology Platform for Lower VOC Wood Coatings and Stains**

- USB Project #: 1940-362-0715 A
- Six years of funding

**High Oleic Soy Hydrophobic Latex and Coatings**

- USB Project #: 1940-362-0715 C
- Second year of funding
## USB SOY OIL BASED PUD

<table>
<thead>
<tr>
<th>Water Contact Angle &gt;100°</th>
<th>Exterior Wood Finish</th>
<th>Competitive Formula</th>
<th>SOY PUD Based Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>

Replacing existing formula in 2019 0.8 million lb annually

Outdoor exposure result 10 months

(U.S. Pat. Appl. No. 14/656,097)
USB PROJECT

USB Project
Soy Based Reactive Diluent

Low VOC
Wood Stain

- Reduce VOC
- Improved dry time
- Improve storage stability
- Good wood penetration
- Tannin block
- Dry with other alkyds
HIGH OLEIC SOY OIL (HOSO) MODIFIED LATEX

HOSO Based Functional Alkyd

Stable for storage

Reactive with functional monomer

Co-polymerization

Features

Incorporation Into Latex

Water beading

Water resistance

CA=88°

Cost friendly
Collaboration with USB

• Over 10 year relationship
• Products containing 10+% Soybean Oil
• Performance equal to better to current competitive products
• Soy PUD has been commercialized
• Soy Reactive Diluent is economical and exceeds performance of current products
• Commercialization is underway
UNIVERSITY OF TENNESSEE/IOWA STATE

Use of High-Oleic Soybean Oil and Soybean Hardstock in Commercializing Soy-based Coating Waxes

• USB Project #: 1840-362-0735-E
• Four years of funding

Developing Coating for Fresh Produce from Commodity and High Oleic Soybean Oil

• USB Project #: 1940-362-0715 F
• First year of funding
Soy-based Wax Coating for Corrugated Paperboard

- Paraffin wax offers excellent water-proofing and strengthening for packaging
- 3 billion lb paraffin coated boxes (40-50% weight of the box) are landfilled per year*
- Industrial trends
  - Pulpability/recyclability
  - Use less coating by applying water based polymer emulsion on surface
- Soy-based EGMD is removable by washing
- Paraffin and silica microparticles improves water resistance

<table>
<thead>
<tr>
<th></th>
<th>Wax Absorption (%)</th>
<th>Wax Washable (%)</th>
<th>Water Absorption (%)</th>
<th>Strength Before Ice Soaking (g)</th>
<th>Strength Reduction After Soaking (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraffin</td>
<td>49.2±0.9</td>
<td>34.0±4.1</td>
<td>15.3±3.2</td>
<td>12,867±496</td>
<td>77.4±3.7</td>
</tr>
<tr>
<td>Soy EGMD</td>
<td>49.1±2.0</td>
<td>85.5±0.7</td>
<td>51.2±1.4</td>
<td>13,233±2,748</td>
<td>89.1±2.0</td>
</tr>
<tr>
<td>Paraffin + 50wt% EGMD</td>
<td>51.3±0.7</td>
<td>86.7±1.9</td>
<td>14.1±3.3</td>
<td>12,489±431</td>
<td>75.4±1.9</td>
</tr>
<tr>
<td>EGMD + 5wt%Micro Silica</td>
<td>50.1±2.1</td>
<td>-</td>
<td>18.0±2.3</td>
<td>15,594±156</td>
<td>72.4±2.3</td>
</tr>
</tbody>
</table>

*(Global Green USA, 2015)
HARD AND HIGH MELTING WAX COATINGS AND INKS

• Potential substitute for hard synthetic waxes
  - FT and PE

• Soy is sustainable, abundant and economical in price

• ISU developed licensable technology

<table>
<thead>
<tr>
<th>Property</th>
<th>Hardwax</th>
<th>Carnauba Wax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>Hard Solid</td>
<td>Hard Solid</td>
</tr>
<tr>
<td>Color</td>
<td>Yellow to brown</td>
<td>Yellow to brown</td>
</tr>
<tr>
<td>Melting Point</td>
<td>145-150 °C</td>
<td>81-86 °C</td>
</tr>
<tr>
<td>Needle Penetration (ASTM D1321)</td>
<td>0.12mm (8.57 mm⁻¹)</td>
<td>0.11mm (9.05 mm⁻¹)</td>
</tr>
<tr>
<td>Water Contact Angle</td>
<td>≈65</td>
<td>≈45</td>
</tr>
</tbody>
</table>
HIGH OLEIC SOYBEAN OIL WAXES – PRODUCE COATINGS

• Produce companies looking for substitutes for Shellac, Carnauba and Paraffin

• Soy wax emulsions have excellent properties:
  - Gloss
  - Adhesion
  - Gas permeability
  - Washability
Soy-based wax has application in a multitude of coating applications

Ester-based wax: performance excelled when blended with paraffin/polymers
  - Pulpability/recyclability of paper
  - Grease and water resistance

Amide-based wax: potential replacement for high melting/hard waxes

HBO-HOSO: Excellent gloss, adhesion, washability and gas permeability

Licensing opportunities available
• Impact Modification of Epoxy Coatings with Soy Oil
• USB Project #: 1840-362-0737 C
• Three years of funding
MODIFICATION OF EPOXY COATINGS

- Epoxy coatings issues
  - Solvent reduction due to VOC regulations
    - Increased viscosity
    - Brittleness
- Biobased impact modifier
  - Acidulated soy oil
- Proprietary compatibilizer
MANDREL BEND
Significant improvement in mandrel bend

At even 15% additive, the results in the ASTM mandrel bend test dramatically improved, at 1/8 in. as opposed to the 1.5 in. bend in the control.
SOLVENT RESISTANCE

• Solvent resistance (1 hour)
  - Solvents
    • Xylene
    • MEK
    • Methanol
  - Scrape with spatula after 1 hour

• All formulations are susceptible to softening with methanol

• Only the more highly filled systems are affected by MEK and xylene
The Soy Oil based impact modifiers in clear and formulated anti corrosive paint systems exhibit the following characteristics:

- Lowers viscosity
- Very low odor
- Lowers cost
- Improves flexibility and impact resistance
- Good solvent resistance
- Enhances corrosion resistance
Soy-based Low-Temperature Powder Coating

- USB Project #: 1940-362-0715 D
- Three years of funding

Attributes:
- High biobased content – 84% in resin
- Low-temperature cure – 135°C vs. 200°C
- Coating flexibility & toughness
- Chemical and corrosion resistance
- Smooth coatings with architectural gloss levels
- Outdoor weathering performance
• Water-Based Bio-Hybrid Technology
• Hybrid technology: polyester + acrylic + oil
• Aqueous dispersion + oxidative cross linking
• Performs and applies like solvent borne (oil based) coatings
• Water based traffic paint
• BECKOSOL AQ® 400
  - Solvent-free short chain alkyd
  - 1 gallon = ~12,000 soybeans
  - USDA BioPreferred Label
Summary

- **Soybean Oil**
  - Abundantly Available
  - High Sustainability Profile
  - Economical

- **Diverse Applications**
  - Coalescent Solvents
  - Reactive Diluents
  - Plasticizers
  - Alkyd Resins/Acrylic Hybrids/High Solids/Emulsions
  - Soy Polyols for PU & Melamine Coatings
  - UV Curable Resins
  - Waxes

US Soybean Board Funding Available
Thank You

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