Growing and Strengthening the Biobased Chemicals Industry

USDA BioPreferred™ Forum
April 1, 2010
Some Industrial and Environmental Section Members
Biorefining
It’s Not Just About Ethanol!

Polyurethanes
Polyesters
Nylon
Lignin
Biofuels
Green Solvents (ethylactate)
Ethanol & Bioethanol
Specialty Chemicals
High Performance Materials
Amino Acids
Pharmaceutical Precursors
Feed Additives

Polyols
Organic Acids
Fibers
Monomers
Polymers

Agriculture Feedstocks (grain and cellulose)

Lactic Acid Technology and Capabilities
Example of a Bio-refinery: Wet Mill

Initial Strategy
- Maximize value from existing infrastructure
Examples of Biochemicals & Biopolymers

- Butanol
- Isobutanol
- Ethanol
- Acrylic Acid
- Propylene Glycol
- 1,3-Propanediol
- Glycolic Acid
- Acetic Acid
- Caprolactam
- Hydroxy Alkanoates
- Adipic Acid
- Isosorbide
- Acrylamide
- Fumaric Acid
- Isosorbide
- Succinic Acid
- 1,4-Butanediol
- Methyl Ethyl Ketone
- Isoprene
- Ethyl Acetate
- Algae Based Chemicals
- Itaconic Acid
- SAP
- Acetone
- PLA
- PHA
- PVC
- PET
- UPR
# Bio-Derived Plastics - First Wave

Recent Advances In Renewable Chemicals
DuPont, NatureWorks, Dow

<table>
<thead>
<tr>
<th></th>
<th>DuPont Bio-PDO (Serona®)</th>
<th>NatureWorks™ PLA</th>
<th>Dow/Crystalev JV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant Scale</strong></td>
<td>45 kTA</td>
<td>140 kTA</td>
<td>350 kTA</td>
</tr>
<tr>
<td><strong>Fermented Product</strong></td>
<td>1,3-Propanediol</td>
<td>Lactic Acid</td>
<td>Ethanol</td>
</tr>
<tr>
<td><strong>Key Processes</strong></td>
<td>Fermentation, Condensation, Polymerization</td>
<td>Fermentation, Oligomerization, Ring-Closing, &amp; Ring-Opening Polymerization</td>
<td>Fermentation, Dehydration, Polymerization</td>
</tr>
<tr>
<td><strong>Initial Product</strong></td>
<td>PDO/TPA Copolymer</td>
<td>Polylactic acid</td>
<td>Ethylene, Polyethylene, Copolymers</td>
</tr>
<tr>
<td><strong>Flexibility</strong></td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
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Availability of New Renewable Raw Materials

Example: Conversion of glucose to 1,3-propanediol (PDO)

Ferment glucose to PDO using patented microorganism

Refine to 99.7% purity

Corn

Glucose

1,3 Propanediol

Courtesy of DuPont Tate & Lyle BioProducts LLC

1Susterra is a trademark of DuPont Tate & Lyle BioProducts LLC
Ashland developed the first commercially available bio-based product in 2003

- ENVIREZ 1807 Resin was first used in SMC applications.
- This was originally developed by Ashland at the request of the United Soybean Board and John Deere

- Ashland continues to invest in the research and development of green resins

  - Commercial products are now available for SMC/BMC, pultrusion, casting, infusion, and general laminating
- Using ENVIREZ SS 70419 Resin
- Application listed on USDA BioPreferred procurement database
  - “Vendura solid surface material manufactured with bio-resin supplied by Ashland Inc.”

Sinks and Surfaces

- ENVIREZ SS 71301 Resin
- Won the 2009 ACMA Green Aces award

Boat Hulls & Decks

- Using ENVIREZ L86300 Series Resin
- Public announcement of full production – January 2010
Polylactic Acid (PLA)

- World's leading biopolymer player
- Proprietary PLA biopolymer marketed under the Ingeo trademark
- Competitive on a cost and performance basis with traditional plastics
  - Superior environmental characteristics
  - Significant manufacturing know-how and an extensive IP position
  - Established global market channels
  - Over 20 applications in more than 70,000 store shelves globally
  - Over 100 million pounds in annual sales volume
- Customers include Wal-Mart, Frito-Lay, and Coca-Cola
# PLA Product Applications

<table>
<thead>
<tr>
<th>Fresh food packaging</th>
<th>Food serviceware</th>
<th>Films/cards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beverages</td>
<td>Nonwovens/fibers</td>
<td>Durables</td>
</tr>
</tbody>
</table>

- Fresh food packaging: Various food items like sandwiches, eggs, and beverages.
- Food serviceware: Cups, spoons, and food packaging items.
- Films/cards: Various film and card products.
- Beverages: Bottles and water packets.
- Nonwovens/fibers: Textile and clothing items.
- Durables: Electronic devices and medical equipment.
Dow Crystalev JV

Polyethylene from Cane - Brazil

- 350 kT of LLDPE (700 MM lbs)
- 120,000 hectares of cane
- Recyclable plastic (CO₂ fixation)
- Cheaper than many fossil sources
- Lower capital footprint
- Walled off from oil volatility
The sugar stream (both xylose [C₅] and glucose [C₆]) is sent to fermentation where an acetogenic process is utilized to ferment the sugars to acetic acid without CO₂ as a by-product. In comparison, traditional yeast fermentation creates one molecule of CO₂ for every molecule of ethanol. Thus the carbon efficiency of the ZeaChem fermentation process is nearly 100% vs. 67% for yeast.
Solvay Renewable PVC Production

From sugar and salt to make plastic

Solvay Indupa’s Brazilian new plant (start in 2010)

60 Kton/year of Bio-Ethylene and 125 Kton/year of Renewable PVC

Reduction of 300 Kton/year of CO₂ emissions
Second Wave Bioproducts Beyond Ethanol And Biodiesel

Bio Conversion – Second Wave Bioprocesses vs. Chemical Processes
Succinic Acid Platform
Production of Succinic Acid

Uses metabolic engineering and metabolic evolution to construct organisms that make high value, high purity, renewable chemicals such as succinic acid from sugar.

Robust and Scalable Process for Succinic Acid
– Faster: reduce capital investment
– Cheaper: nutrients, energy, process chemicals
– Cleaner: fermentation and downstream separation/purification are integrated

“We are competitive at today’s oil prices and down to less than $45/barrel equivalent!”

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“Top Value Added Chemicals from Biomass”
- U.S. DOE
Roquette the partner in bio-succinic acid

Producing succinic acid via biological routes has several advantages:

1. Lower environmental impact
   1. No use of fossil fuels (crude oil)
   2. Bio-renewable feedstocks
   3. Absorbs instead of emits CO₂
   4. Cost proposition allows for high volume green chemicals and materials

2. New biobased & biodegradable applications feasible
   1. Production of ‘green’ plastics like PBS (for a.o. agricultural films)
   2. Biobased fibers for clothing
   3. Bio-based resins (e.g. polymer of bio-succinic acid and isosorbide [biobased product made by Roquette])
Third Wave - Plant Expression

Synthetic Biology & Systems Biology
Contributions to Biofuels, Renewable Chemicals, Specialty Chemicals, Bioproducts
# Surfactants Platform

Using Synthetic Biology

<table>
<thead>
<tr>
<th>Software</th>
<th>Robotics</th>
<th>Biology</th>
<th>Manufacturing</th>
<th>Chemicals</th>
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</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Software Image" /></td>
<td><img src="image2.png" alt="Robotics Image" /></td>
<td><img src="image3.png" alt="Biology Image" /></td>
<td><img src="image4.png" alt="Manufacturing Image" /></td>
<td><img src="image5.png" alt="Chemicals Image" /></td>
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## Specialty Chemicals Surfactants

<table>
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<tr>
<th>Foaming agents</th>
<th>Emulsifiers</th>
<th>Dispersants</th>
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<tr>
<td><img src="image6.png" alt="Foaming agents Image" /></td>
<td><img src="image7.png" alt="Emulsifiers Image" /></td>
<td><img src="image8.png" alt="Dispersants Image" /></td>
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- **$24 billion market**
- **Annual global production 13 million metrics tonnes**
Surfactant Manufacturing Today

- 32 billion kg CO₂ annually
- Equal to burning 3.6 billion gallons of gasoline annually
- Palm and coconut plantation expansion threatens rainforest

Surfactant Manufacturing Tomorrow
Terpenes Provide Processing Advantages

• Historically, terpenes have been too expensive to produce through traditional manufacturing processes
  ✓ Chemical synthesis
  ✓ Extraction

• Allylix proprietary metabolic engineering fermentation platform offer significant advantages:
  ✓ Step change in the cost of production
  ✓ Sustainable
  ✓ Stable supply

• Allylix technology opens the use of terpenes broadly across all market
## Value In Multiple Industries

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<tr>
<th>Industry</th>
<th>Example products</th>
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<tbody>
<tr>
<td>Flavor &amp; Fragrances</td>
<td>Menthol</td>
</tr>
<tr>
<td>Insect Repellents &amp; Crop Protection</td>
<td>Nootkatone</td>
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<tr>
<td></td>
<td>Geraniol</td>
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<tr>
<td></td>
<td>Citranella</td>
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<tr>
<td>Natural Sweeteners</td>
<td>Steviaside</td>
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<td></td>
<td>Rebaudioside</td>
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<tr>
<td>Biofuels</td>
<td>Terpene</td>
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<td></td>
<td>hydrocarbons</td>
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<tr>
<td>Pharmaceuticals</td>
<td>Taxol</td>
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Biochemicals Commercialized from Genencor

- Lysine
- Threonine
- Tryptophan
- Indigo
- Biotin
- Ascorbic Acid

- PDO polymer DuPont Tate & Lyle
  - Sorona™ carpets, cosmetics, etc.
  - 40% less energy, GHG reduced 20%

- Biosioprene™: strategic biobased alternative
  - Major potential to reduce tire & rubber industry dependence on oil, natural rubber
  - Broad applications in rubber, adhesives, fuel
  - LCAs to ensure process will be sustainable

Concept Biolsoprene™ Tire for the UN Climate Summit, Dec 2009, CPH
Biobased Polymers Derived from Itaconic Acid

Applications for Polyitaconic Acid

- pH, Biocides
- Viscosity modifiers
- Filers, diserson stabilizers
- Coalescing aids
- Pigments
1,4-Butanediol Platform
Sustainable Process

**Genomatica’s Process Overview**
- Direct conversion to BDO
- 100% renewable BDO
- Cost-advantaged (even at $50/bl oil)
- Over 50% lower fossil energy
- Reduced CO₂ and GHG emissions

**BDO Today**
- 2.5B lbs/yr. ($3B market)
- Key chemical intermediate
- Range of applications:
  - Polyesters (PBT)
  - Polyurethanes (TPU)
  - Co-polyester ethers
  - Co-polymers (spandex)
**EDGE - BioAcrylic Acid**

**EDGE Technology Platform**
Efficiency Directed Genome Engineering

- Massively Parallel Genetic Manipulations
- Quantitative Experimental Design
- Comprehensive & High Resolution Parallel Processing

**Acrylic Acid Market Opportunity**

**$10 B market**
4% growth
Produced by 2-step catalytic oxidation of propylene

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**Producer Capacity Share**

- BASF
- Rohm&Haas
- Dow
- Shokubai
- Other

Global capacity = 4.3M mt

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**End-Use Demand Share**

- SuperAbs
- Coatings
- Adhesives
- Water Treat
- Textiles
- Other
- Detergents
- Other

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**Platform 3-HydroxyPropionate (3-HP)**

BioAcrylic < $0.50/lb
Microalgae Converts Biomass to Bio-based Chemicals

• Indirect photosynthesis bio-production

• Process uses microalgae to convert biomass directly into bio-based chemicals and biofuels

• A process performed in standard commercial fermentation facilities cleanly, quickly, and at low cost and large scale

• Manufactured thousands of gallons of oil and hundreds of tons of bio-chemicals for replacing fossil petroleum and plant oils in a diverse range of products from oleochemicals to cosmetics and food
Summary

- BIO was first organization to endorse Farm Bill’s energy title 2001 and 2002
  - Supported the expanded Bio-Prefferred Bill 2008
    - Proposed voluntary labeling program offers potential to expand biobased markets, “USDA Certified Biobased Product,” label
- Role of the entire value chain from feedstocks to intermediates (biomonomers and biopolymers) to final products needs to be recognized to achieve maximum potential
- BIO strongly supports the inclusion of biobased intermediates as eligible to receive the label under current rulemaking
World Congress on Industrial Biotechnology

- World largest conference on industrial biotech
- June 27-30, 2010
- Washington, D.C. – Gaylord Resort and Convention Center
- Over 200 speakers
- First year for investor sessions for CEO presentations
- 1,300 attendees – www.BIO.org/worldcongress