Susterra® Propanediol
Synthetic Leather

Performance is in our nature.

May 11, 2016
Who is DuPont Tate & Lyle?

DTL is a joint venture formed in 2004 between DuPont and Tate & Lyle to produce 1,3 propanediol (PDO) from corn starch, a sustainable & renewable resource.

DuPont is a world leader in science and innovation across a range of disciplines, including agriculture and industrial biotechnology, chemistry, biology, materials science and manufacturing. CY2015 revenues were $35 billion.

Tate and Lyle is a global provider of renewable ingredients, solutions and services to the food, beverage and industrial customers. Revenues were $4.3 billion for Fiscal Year ending March 31, 2015.
Process Technology
Renewably sourced feedstocks are harvested, fermented, and refined to manufacture Susterra® propanediol.

Harvest
Renewably sourced feedstocks are harvested, dried and then wet-milled to create a range of carbohydrate rich feedstocks such as glucose.

Fermentation
Glucose is converted into 1,3 propanediol using a patented microorganism under exact temperatures and conditions.

Refining
The 1,3 propanediol is refined to a final purity of 99.7% by deactivating and removing the microorganism, water, and other byproducts.
Production

Biotechnology enables our global headquarters and production in Loudon, Tennessee to produce a stable supply of renewably sourced 1,3 propanediol.

Awards
- 2003 EPA Presidential Green Chemistry Award
- 2007 ACS Heroes of Chemistry Award
- 2009 ACS-BIOT Industrial Biotechnology Award
- 2010 State of Tennessee Governor’s Award for Trade Excellence

Production
- Started November 2006
- Capacity expanded 35% in 2010
- Current Capacity = 140 million lb.
Susterra® Propanediol Process Flow

Fermentation

Dextrose
Air
Water
Biocatalyst
Nutrients

CO₂-enriched air

Water
Bioresiduals

Re-use as fertilizer

Distillation

Product Storage Tanks

Trace Impurities

Not Meet Specification

QC

Meet Specification

Quality Checks
PDO Purity (GC)
Color (Hazen)
Water (Karl Fischer)
Appearance (Visual)

Susterra® 1,3-Propanediol

World’s largest E. coli fermentation

Re-use as fertilizer
Field Corn vs. Sweet Corn

Susterra® propanediol is derived from U.S. Field Corn

Yellow Dent or “Field Corn”:
90.6 MM planted acres
14.2 B bushels produced
Crop Value: $51.9 B

Sweet Corn:
0.555 MM planted acres
137 MM bushels produced
Crop Value: $1.02 B

Yellow Dent Facts:
• Grown on over 99% of U.S. corn field acres
• Produced for ethanol, livestock feed, cereals, and other manufactured goods
• Considered a grain
• Harvested when kernels are dry and mature

Sweet Corn Facts:
• Grown on less than 1% of U.S. corn field acres
• Consumed by humans
• Considered a vegetable
• Harvested when kernels are soft and immature

Source: Field corn statistics - U.S. Department of Agriculture, June 2015
Sweet corn statistics - U.S. Department of Agriculture, 2014
Field Corn

Susterra® propanediol is a minimal part of the FSI segment. The usage would fall under the “Core Usage” Starch segment (1.8%).

DuPont Tate & Lyle Susterra® propanediol accounts for a fraction of the 1.8% of starch-based products.

Corn starch as a raw material for biomaterials does not have a material impact on the price or supply of corn.

Source: USDA, ERS Feed Outlook, Jan 14, 2015; ProExporter Network Crop Year Ending Aug 31, 2015

Notes:
DDG = Distillers Dried Grain – co-product of dried milled ethanol production that is used as animal feed
Field Corn
Susterra® propanediol utilizes the starch in the field corn while the other components are harvested for different applications including animal feed for livestock.

Yellow Dent Corn Components:
- 62% Starch
- 19.2% Protein & Fiber
- 15% Moisture
- 3.8% Corn Oil

One bushel of wet-milled field corn

Produces

<table>
<thead>
<tr>
<th>1.5 pounds of crude corn oil</th>
<th>13.5 pounds of gluten feed</th>
<th>2.6 pounds of gluten meal</th>
<th>31.5 pounds of starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used in consumer &amp; industrial products</td>
<td>Used in animal feed</td>
<td>Used in animal feed</td>
<td>Used as the feedstock for Susterra® propanediol</td>
</tr>
</tbody>
</table>

Source: Tate & Lyle; National Corn Growers Association
Susterra® Propanediol
From the Field to Market Applications

DuPont Pioneer hybrids → Corn → Glucose → Bio-PDO™ → DuPont enzymes → DuPont microorganism → Fiber

DuPont™ Sorona® → Carpet → Apparel → Auto

Zemea®
- Cosmetics and Personal Care
- Food and Flavors
- Laundry and Cleaning
- Pharmaceuticals

Susterra®
- Heat Transfer Fluids
- Polyurethanes
- Unsaturated Polyester Resins
- Paints, Coatings, and Inks
- Deicing Fluids

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Susterra® Propanediol

What is it?
• A pure, petroleum-free derived glycol
• 100% sustainably and renewably sourced
• Used in a range of applications

How is it made?
• Made by a fermentation process derived from glucose
• Made in the USA
• USDA 100% Certified Bio-Based Product
Life Cycle Analysis (LCA)

LCA is the only standardized method to evaluate the environmental footprint of a whole supply chain. Energy consumption and Green House Gas (CO₂) emissions are key factors in determining environmental footprint.

Cradle-to-gate

Cradle-to-grave

Biodegradation of product results in no net CO₂ increase

- Raw Material Acquisition
- Transportation
- Manufacturing
- Use/Reuse/Maintenance
- Waste Management

- Recycle

- Raw Materials
- Energy

- Co-products
- Air Emissions
- Waterborne Wastes
- Solid Wastes
Life Cycle Analysis
Susterra® propanediol

From “cradle to gate” (extraction and production prior to delivery to the consumer), Susterra® propanediol produces 56% less greenhouse gas emissions and consumes 42% less nonrenewable energy than propylene oxide-based propanediol. Compared with butanediol (BDO), Susterra® propanediol produces 52% less greenhouse gas emissions and uses 32% less nonrenewable energy from cradle to gate.
Susterra® Propanediol Polyurethanes
Key Applications
Susterra® propanediol: A high performance, bio-based building block for polyurethane applications

Footwear
- TPU elastomers
- TPU waterproof breathable films
- PU foams
- Hot melt adhesives
- PU synthetic leather

Performance Textiles
- TPU waterproof breathable films
- PU synthetic leather (i.e. accessories)

Furniture and Automotive
- TPU elastomers
- PU foam
- Hot melt adhesives
- PU synthetic leather
Polyurethane Production

Susterra® propanediol can be used as a chain extender or polyol

- **Susterra® propanediol**
- **BDO**
- **AA/SA**
- **BDO/EG/DEG**

**Chain Extender**

**Polyester Polyol**

**Isocyanate**

- **TPU**
- **PU Leather**
- **PU Adhesives**
- **PU Coatings**

**End User**
TPU Polymer Structure
A versatile polymer chemistry

- Susterra® propanediol
- Ethylene Glycol
- 1,4-Butane Diol
- 1,6-Hexane Diol
- Chain Extender
- Urethane Linkages

- Polyol
- Di-isocyanate

- Hard Segment
- Soft Segment

- Susterra® PDO adipate
- BDO/HDO adipate
- EG/BDO adipate
- PTMEG
- Polycaprolactone
- Polycarbonate

- MDI
- TODI
- HDI
# Susterra® Propanediol

Diol comparison – chemical structure and property comparison

<table>
<thead>
<tr>
<th>Common</th>
<th>Ingredient</th>
<th>CAS#</th>
<th>Formula</th>
<th>Structure</th>
<th>MW</th>
<th>BP, °C</th>
<th>MP, °C</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene Glycol</td>
<td>1,2-Ethanediol</td>
<td>107-21-1</td>
<td>C2H6O2</td>
<td><img src="Image" alt="Structure" /></td>
<td>62.1</td>
<td>197.6</td>
<td>-12.7</td>
<td>1.116</td>
</tr>
<tr>
<td>Propylene Glycol</td>
<td>1,2-Propanediol</td>
<td>57-55-6</td>
<td>C3H8O2</td>
<td><img src="Image" alt="Structure" /></td>
<td>76.1</td>
<td>187.3</td>
<td>-60</td>
<td>1.038</td>
</tr>
<tr>
<td>Propanediol</td>
<td>1,3-Propanediol</td>
<td>504-63-2</td>
<td>C3H8O2</td>
<td><img src="Image" alt="Structure" /></td>
<td>76.1</td>
<td>214</td>
<td>-24</td>
<td>1.053</td>
</tr>
<tr>
<td>MPDiol</td>
<td>2-Methyl-1,3-Propanediol</td>
<td>2163-42-0</td>
<td>C4H10O2</td>
<td><img src="Image" alt="Structure" /></td>
<td>90.1</td>
<td>221</td>
<td>-91</td>
<td>1.015</td>
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<tr>
<td>1,4 BDO</td>
<td>1,4-Butanediol</td>
<td>110-63-4</td>
<td>C4H10O2</td>
<td><img src="Image" alt="Structure" /></td>
<td>90.1</td>
<td>230</td>
<td>16</td>
<td>1.017</td>
</tr>
<tr>
<td>Neopentyl Glycol</td>
<td>2,2-Dimethyl-1,3-Propanediol</td>
<td>126-30-7</td>
<td>C5H12O2</td>
<td><img src="Image" alt="Structure" /></td>
<td>104.1</td>
<td>208</td>
<td>127</td>
<td>~1.05</td>
</tr>
<tr>
<td>DEG</td>
<td>Diethylene Glycol</td>
<td>111-46-6</td>
<td>C4H10O3</td>
<td><img src="Image" alt="Structure" /></td>
<td>106.1</td>
<td>245</td>
<td>-10</td>
<td>1.118</td>
</tr>
<tr>
<td>Hexylene Glycol</td>
<td>2-Methyl-2,4-Pentanediol</td>
<td>107-41-5</td>
<td>C6H14O2</td>
<td><img src="Image" alt="Structure" /></td>
<td>118.2</td>
<td>197</td>
<td>-40</td>
<td>0.925</td>
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<tr>
<td>DPG</td>
<td>Dipropylene Glycol</td>
<td>25265-71-8</td>
<td>C6H14O3</td>
<td><img src="Image" alt="Structure" /></td>
<td>134.17</td>
<td>231</td>
<td></td>
<td>1.023</td>
</tr>
</tbody>
</table>
Susterra® Propanediol
Structural Differences and the Odd-Even Effect

The odd even effect varies the packing of the hard block segments, and results in unique mechanical properties of the final product.

1,3 PDO hard block

1,4 BDO hard block

Dipole induces bending and strain

Staggered packing gives no dipole

Long hydrogen bond

Short hydrogen bond

Source:
O. Bayer, Agnew. Chem., A59, 257 (1947)
Synthetic Leather
Polyurethane Synthetic Leather

Layers with Average Weight Percent

- Susterra® PDO is used in the PU skin coating.
- Based on bio-content needs we can explore use in the top coat or form layer
Susterra® Propanediol
PU Leather (HS%= 25 wt%) Physical Properties

• Taber results are consistently higher when Susterra® PDO is incorporated into the PU leather indicating enhanced abrasion performance.
• ASTM D 2097 Flex-o-meter testing run at -20°C indicates improved flexibility even at temperature when PU leather can fail and crack.
• All samples pass Methyl Ethyl Ketone solvency test indicating good chemical resistance

<table>
<thead>
<tr>
<th>Sample</th>
<th>Molecular weight</th>
<th>MEK/30min (Solvent resistance)</th>
<th>-20°C/ 50000 cycles (flex test)</th>
<th>Taber - H22 1kg/cycle (Abrasion resistance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA/Susterra® PDO</td>
<td>2000</td>
<td>Pass</td>
<td>Pass</td>
<td>700</td>
</tr>
<tr>
<td>AA/BDO</td>
<td>2000</td>
<td>Pass</td>
<td>Crack</td>
<td>900</td>
</tr>
<tr>
<td>AA/Susterra® PDO</td>
<td>3000</td>
<td>Pass</td>
<td>Pass</td>
<td>2000</td>
</tr>
<tr>
<td>AA/BDO</td>
<td>3000</td>
<td>Pass</td>
<td>Crack</td>
<td>1000</td>
</tr>
<tr>
<td>AA/Susterra® PDO/EG</td>
<td>2000</td>
<td>Pass</td>
<td>Pass</td>
<td>1100</td>
</tr>
<tr>
<td>AA/BDO/EG</td>
<td>2000</td>
<td>Pass</td>
<td>Pass</td>
<td>1000</td>
</tr>
<tr>
<td>AA/Susterra® PDO/EG</td>
<td>3000</td>
<td>Pass</td>
<td>Pass</td>
<td>1100</td>
</tr>
<tr>
<td>AA/BDO/EG</td>
<td>3000</td>
<td>Pass</td>
<td>Pass</td>
<td>1000</td>
</tr>
</tbody>
</table>
Susterra® Propanediol
PU Leather (HS%= 40 wt%) Physical Properties

- Increasing the hard segments in PU leather does change the enhanced abrasion results.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Molecular weight</th>
<th>MEK/30min (Solvent resistance)</th>
<th>Taber - H22 1kg/cycle (Abrasion resistance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA/Susterra® PDO</td>
<td>2000</td>
<td>Pass</td>
<td>1200</td>
</tr>
<tr>
<td>AA/BDO</td>
<td>2000</td>
<td>Pass</td>
<td>1100</td>
</tr>
<tr>
<td>AA/Susterra® PDO</td>
<td>3000</td>
<td>Pass</td>
<td>900</td>
</tr>
<tr>
<td>AA/BDO</td>
<td>3000</td>
<td>Pass</td>
<td>700</td>
</tr>
<tr>
<td>AA/Susterra® PDO /EG</td>
<td>2000</td>
<td>Pass</td>
<td>1500</td>
</tr>
<tr>
<td>AA/BDO/EG</td>
<td>2000</td>
<td>Pass</td>
<td>500</td>
</tr>
<tr>
<td>AA/Susterra® PDO/EG</td>
<td>3000</td>
<td>Pass</td>
<td>800</td>
</tr>
<tr>
<td>AA/BDO/EG</td>
<td>3000</td>
<td>Pass</td>
<td>800</td>
</tr>
</tbody>
</table>
Susterra® Propanediol
PU Leather Abrasion Testing

Susterra® propanediol may enhance abrasion resistance when used in the synthetic leather skin coat layer.

Taber abrasion testing (H22 1kg/cycle) on various skin coat samples
Each sample was run until 1500 cycles.
Susterra® propanediol may be polymerized to form PO3G which may be used as 100% bio-based polyol.

PO3G or PTMEPOL is not a DuPont Tate & Lyle product. Third parties license a DuPont technology in order to manufacture and sell PO3G as separate entities.

For more property information on PO3G please contact Allessa or SK Chemicals
Susterra® Propanediol
Synthetic Leather

- Enhance abrasion resistance
- Good Elasticity and soft feel
- Improved flexibility at low temperatures
- Delivers vibrant, rich colors with less dye

Performs beautifully.

Performance is in our nature.
Laurie Kronenberg

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