Performance is in our nature.

March 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.
Susterra® Propanediol Process Flow

Fermentation
- Dextrose
- Air
- Water
- Biocatalyst
- Nutrients

CO₂-enriched air

Separations
- Water
- Bioresiduals

Distillation

Product Storage
- Susterra® 1,3-Propanediol

Re-use as fertilizer

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

Meet Specification

Not Meet Specification

Recycle

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 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
DuPont Pioneer hybrids → Corn → Glucose → Bio-PDO™ → DuPont TM Sorona® → Fiber

- 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
• GRAS, Halal, Kosher
• Ingredient for use in Heat Transfer Fluids with Incidental Food Contact (HTX-1)
Susterra® Propanediol

Performance advantages in heat transfer fluids

- Improved viscosity at lower temperatures compared to PG
- Excellent freeze point depression for aqueous solution applications
Susterra® Propanediol
Glycol comparison – chemical structure and property comparison

1,2-Propanediol (PG) and 1,3-Propanediol (PDO) have the same formula and molecular weight.

The difference between PG and PDO is the structure of the molecule. PDO is more linear giving it a higher BP and lower viscosity.

<table>
<thead>
<tr>
<th>Common</th>
<th>Ingredient</th>
<th>CAS#</th>
<th>Formula</th>
<th>Structure</th>
<th>Mol. Wt.</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>C2H602</td>
<td><img src="image1" 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>C3H802</td>
<td><img src="image2" 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>C3H802</td>
<td><img src="image3" alt="Structure" /></td>
<td>76.1</td>
<td>214</td>
<td>-24</td>
<td>1.053</td>
</tr>
</tbody>
</table>
Susterra® Propanediol

Glycol comparison – property comparison

Susterra® propanediol exhibits lower freeze points at higher percentages of glycol.

Freeze Points of Aqueous Glycol Solutions

-140 -120 -100 -80 -60 -40 -20 0 20 40 60

0 10 20 30 40 50 60 70 80 90 100

Glycol Volume, %

Degrees, F

Ethylene Glycol 1,3 Propanediol Propylene Glycol
Susterra® Propanediol
Glycol comparison – low temperature viscosity

Susterra® propanediol exhibits lower viscosity under low-temperature conditions

Glycol Viscosity Comparison

Temperature, °C

Viscosity, cps

Propylene Glycol
1,3 Propanediol
Ethylene Glycol
Susterra® Propanediol

Glycol comparison – pump power ratio

**Objective:** Determine the amount of energy needed to pump fluid 1 (propylene glycol) relative to fluid 2 (1,3-propanediol) in order to get the same heat transfer performance.

\[ PPR_{12} = \left( \frac{\mu_1}{\mu_2} \right)^{1.95} \left( \frac{\rho_1}{\rho_2} \right)^{-0.05} \left( \frac{k_1}{k_2} \right)^{-2.3} \left( \frac{C_p_1}{C_p_2} \right)^{-1.05} \]

<table>
<thead>
<tr>
<th>Properties at -10°C</th>
<th>40.5 wt % PG</th>
<th>40 wt% Propanediol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Viscosity (cP)</td>
<td>24.48</td>
<td>16.5</td>
</tr>
<tr>
<td>Density (0°C), g/ml</td>
<td>1.05</td>
<td>1.06</td>
</tr>
<tr>
<td>Specific Heat (kJKg^{-1}K^{-1})</td>
<td>3.602</td>
<td>3.495</td>
</tr>
<tr>
<td>Thermal Conductivity (Wm^{-1}K^{-1})</td>
<td>0.374</td>
<td>0.39</td>
</tr>
<tr>
<td>Kinematic Viscosity (cSt)(^6)</td>
<td>23.3</td>
<td>15.5</td>
</tr>
<tr>
<td>Fp (°C)</td>
<td>-20</td>
<td>-20</td>
</tr>
</tbody>
</table>

**PPR\(_{12} \) @ -10°C = 2.4**

The power required to pump a 40% PG fluid at -10°C is 2.4 times that of the pumping energy as a 40% Susterra® propanediol fluid.

Susterra® Propanediol
Glycol comparison – pump power usage

Objective: Compare the pump power usage performance using two different heat transfer fluids for a food refrigeration system.

Operating temperature: 32 °F
Flow: 175 gpm
Centrifugal Pump: 5 hp
Head: 50 ft

Using hydraulic institute standards to adjust for viscous liquids determines that pump power for Susterra® propanediol led to a 8.9% reduction in power usage.

<table>
<thead>
<tr>
<th>Property</th>
<th>Propanediol, 30%</th>
<th>Propylene Glycol, 30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freezing point, °F (°C)</td>
<td>9.4°F (-12.6°C)</td>
<td>9.2°F (-13°C)</td>
</tr>
<tr>
<td>Density (0°C), kg/m³</td>
<td>1026</td>
<td>1030</td>
</tr>
<tr>
<td>Kinematic viscosity, centistokes</td>
<td>42</td>
<td>69</td>
</tr>
<tr>
<td>Power, (kW)</td>
<td>3.1</td>
<td>3.4</td>
</tr>
<tr>
<td>Power savings</td>
<td>8.9%</td>
<td>- n/a -</td>
</tr>
</tbody>
</table>

Source: Hydraulic Institute Standards
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
Raw Material Acquisition
Raw Materials
Manufacturing
Transportation
Recycle
Use/Reuse/Maintenance
Waste Management

Cradle-to-grave
Energy
Transportation
Recycle
Use/Reuse/Maintenance
Waste Management

Biodegradation of product results in no net CO₂ increase

CO₂

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 petroleum-based 1,3-propanediol. Compared with propylene glycol, Susterra® propanediol produces 42% less greenhouse gas emissions and uses 38% less nonrenewable energy from cradle to gate.
Laurie Kronenberg

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