Polymers for Better Living™

BIO World Congress on Industrial Biotechnology
May 14, 2014
Itaconix Corporation is the world leader in polymers from itaconic acid. We produce polymers for everyday applications that achieve two essential objectives - performance and sustainability.
Unique Position of Itaconic Acid within Organic Acids

- 2 carboxylic acid groups
- 1 vinyl bond

- Production by fermentation
- Production from petroleum
- Size indicates market volume
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**Functional Acid Groups**

- Citric Acid
- Succinic Acid
- Lactic Acid
- Itaconic Acid
- Acrylic Acid

**Ability to Polymerize**
Carboxylic Acid Density

- Succinic acid
- Citric acid
- Itaconic acid
- Acrylic acid
- Methacrylic acid
- Lactic acid

Carboxylic Acids as % of Molecular Weight
Process Time for Itaconic Acid Polymerization

<table>
<thead>
<tr>
<th>Process Time</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 hours</td>
<td>Tate, et al Pfizer, 1960</td>
</tr>
<tr>
<td>8 hours</td>
<td>Swift, et al Rohm &amp; Haas, 1993</td>
</tr>
<tr>
<td>1 hour</td>
<td>Durant, et al UNH/Itaconix, 2008</td>
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</tbody>
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Itaconix Polymers from Itaconic Acid

- Esterification
- Polymerization
- Cross-linked Polymers
- Linear Polymers
- Emulsion Polymers

- Itaconix® DSP
- Itaconix® SAP
- Itaconix® LTX
- Itaconic Acid
- Esterification
- Polymerization

Apr 17 2014
Tate & Lyle - Confidential
Itaconix® DSP™
Low molecular weight linear polyitaconic acid partially neutralized with sodium salt

- Free-flowing granulate
- 100% water soluble
- Off-white color, no odor
- Number average molecular weight of 1500g to 15000g per mole
- Excellent capacity for binding metal ions
- 100% bio-based
- Readily biodegradable
Itaconix® DSP™ Polymers Have Superior Calcium Binding Capacity

Stoichiometric binding capacity at pH 11 expressed as mg CaCO₃/g chelant
Itaconix® DSP™ Polymers

Natural Products Association  Design for the Environment

October 2013
Itaconix® DSP™ 2K is the first polymer to gain approval for CleanGredients
Itaconix® DSP™ - Improving Performance of Leading Detergents & Cleaners

Powder & Liquid Laundry Detergents

Automatic Dishwasher Detergent

Hard Surface Cleaners
Worldwide Addressable Market for Itaconix Polymers

- Emulsion
- Itaconix DSP
- High Mw Linear
- Cross-Linked

6.3 million tons
Worldwide Addressable Market for Itaconic Acid

10.8 million tons
Current Itaconic Acid Market

Supply

• 70 KT of worldwide fermentation capacity
• 3 large facilities + 4 smaller facilities in China using C6 feedstock
• One repurposed US facility using C6 feedstock

Demand

• Primary current use is as a co-monomer in emulsion polymers
• Less than 40 KT of worldwide demand
Routes to Itaconic Acid

Current

• Fermentation of glucose with *A. terreus*

Alternatives

• Fermentation of hemicellulose sugars with *A. terreus*
• Fermentation of glycerol with *A. terreus*
• Biotransformation of citric acid
• Upgrading succinic acid
• Fermentation of glucose with *A. niger*
• New organisms?
Fermentation of Glucose to Itaconic Acid with *A. terreus*

**Rhone Poulenc Patent US5231016**

- Yield 58.7%
- Titer 74.1 g/L
- Rate 0.93 g/L/hr

Glucose → Itaconic Acid

*Aspergillus terreus*
Fermentation of Glycerol to Itaconic Acid with *A. terreus*

Rhone Poulenc Patent US5457040

Yield 49.6%
Titer 49.6 g/L
Rate 0.22 g/L/hr

Glycerol \[\rightarrow\] Itaconic Acid

*Aspergillus terreus*
Fermentation of C5 Sugars to Itaconic Acid with *A. terreus*

10% yield loss to glucose fermentation

**Sugars from hemicellulose**

**Aspergillus terreus**

**Itaconic Acid**
Biotransformation of Citric Acid to Itaconic Acid

Theoretical yield = 67%
Enzymes require pH 5-8

Citric Acid → Itaconic Acid

Aconitase enzyme

Cis-Aconitate Decarboxylase enzyme
Upgrading Succinic Acid to Itaconic Acid

Succinic Acid → Dimethylsuccinate → Itaconic Acid

50% yield on dimethylsuccinate

Methanol

Formaldehyde
Routes to Itaconic Acid

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Itaconix – Developing Itaconic Acid Production

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✓ Itaconix capabilities
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  • New organisms?????????????

✓ Itaconix capabilities
Future of Itaconic Acid

IA 2.0

- Continued growth in demand from new polymers
- Renewed IA production in North America focused on polymer production efficiencies
- Fermentation advances from strain development

IA 3.0

- Emerging growth in demand from building blocks
- IA production in Europe
- Fermentation from hemicellulose sugars
- Major strain advance
Itaconic Acid Volume Development

Kilotons

2010 IA 2.0 IA 3.0

Building Blocks Itaconix Polymers Low % Co-Monomer

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