Designing the bio-polyesters of tomorrow through ring-opening polymerization

Patrick Farquet | Sulzer Chemtech Ltd

10th edition of our Circular Biobased Products Symposium
Bio-polyesters

High carbon and oxygen yields from first and second generations feedstocks

Polyester: The ester linkage

Bio-polyesters are excellent carbon and oxygen storage materials from biomass feedstocks
**PLA – “Shining star” of bio-based polyesters**

PLA has the best yield from raw materials to polymers compared to other bio-plastics

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**1^st Generation: Sugar Cane / Beet / Wheat / Corn / Tapioca**

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar Cane / Beet</td>
<td>11 / 8 ton*</td>
</tr>
<tr>
<td>Wheat / Corn</td>
<td>3.7 / 2.6* ton</td>
</tr>
</tbody>
</table>

Sugar Platform:
- 1.5 – 1.8 ton Sucrose
- 1.5 – 1.8 ton Glucose

1.3 ton Lactic acid ➔ 1 ton PLA

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**Advantages**

- Renewable raw material
- Potential of localization of supply chain for raw material
- The only viable and scalable bio-based alternative to fossil plastics
- Reduced GHG emission compared to fossil-based plastics

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*dry basis
Global bio-polymer demand is surging
Growth mainly driven by bio-polyesters

Why Bio-polyesters

Compared to other bio-polymers, biopolymers:

1. Often a better CO₂ footprint due to their ability to keep carbon and oxygen in the polymer backbone
2. Can have various end-of-life options (i.e. composability, biodegradability), recycling or incineration.

Biopolymer Production Capacities

© European Bioplastics
PLA: Sulzer’s main involvement in bio-polyesters

Market leader for technology licensing from lactide to PLA

- Lactic Acid
- Lactide
- PLA

Crude lactide purification
Ring opening polymerization technology
**Sulzer PLA (Poly lactic acid) technology deployment**

*Our long-standing renewable carbon success story*

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1991</td>
<td>First feasibility test for L-lactide (monomer)</td>
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<tr>
<td>1995</td>
<td>First installation of a full automated pilot plant for lactide monomer in Asia</td>
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<tr>
<td>2001</td>
<td>5 kta, Synbra (NL)</td>
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<tr>
<td>2002</td>
<td>First full-scale demonstration plant for lactide production 1 kta, (Japan)</td>
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<tr>
<td>2007</td>
<td>First pilot plant in Switzerland 0.2 kta, Sulzer (Switzerland)</td>
</tr>
<tr>
<td>2011</td>
<td>1 kta, Sulzer (Switzerland)</td>
</tr>
<tr>
<td>2012</td>
<td>10 kta, Jiangsu Supla (Asia)</td>
</tr>
<tr>
<td>2015</td>
<td>5 kta, Synbra (NL)</td>
</tr>
<tr>
<td>2018</td>
<td>75 kta, Total Corbion PLA (Asia)</td>
</tr>
<tr>
<td>2020</td>
<td>30 kta, B&amp;F (China)</td>
</tr>
<tr>
<td>Under execution</td>
<td>75 kta Natureworks (Thailand)</td>
</tr>
<tr>
<td></td>
<td>30 kta Yangzhou Huitong Biological New Material (China)</td>
</tr>
<tr>
<td></td>
<td>75 kta Jindan New Biomaterials (China)</td>
</tr>
</tbody>
</table>
Sulzer Chemtech – Division of the Sulzer group
We are committed to sustainable innovation

**Sulzer Chemtech**
*Our technologies*
- Mass transfer
- Thermal separation
- Mixing and reaction
- Polymerization and foaming
- Hydrotreating

**Sustainable Innovation**
*Our development areas*
- Recycling
- CO₂ capture and utilization
- Biofuels / bio-chemicals
- Bio-polymers and bio-monomers

**Bio-polymers/monomers**
*Focused on bio-polyesters*
- Novel technologies for sustainable biopolyester production
- Bioplastic applications development
- Bio-foaming technology
Sulzer’s role in bio-polyesters
Where we contribute to a sustainable plastics economy

Biomass
- Extraction

Bio-precursors, e.g.
- Cellulose, starch, sugars, oils
- Fermentation
- Catalysis

Linear bio-compounds
- Purification
- Standardization

Synthesis grade,
- linear bio-compounds

End-of-life treatments

CO₂, H₂O, Compost

Consumer goods
- Recycling
- Processing

Bioplastics
- Polymerization

Polymer-grade bio-monomers
Sulzer’s role in bio-polyesters
Where we contribute to a sustainable plastics economy

Biomass
- Extraction
- High diversity
- Low standardization

Bio-precursors, e.g.
- Cellulose, starch, sugars, oils
- Strongly dependent on type of biomass

Linear bio-compounds
- Fermentation
- Catalysis
- Wide number of organisms and processes

Synthesis grade,
- Linear bio-compounds
- Purification
- Specific to feedstock and impurities

High quality required
- No commodity goods

Standardization

End-of-life treatments
CO₂, H₂O, Compost

Consumer goods
- Processing
- Recycling
- Broad diversity of applications and requirements

Bioplastics
- Polymerization
- Premium price
- Need for application technology
- No commodity goods

Polymer-grade bio-monomers
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Extraction
Fermentation
Purification

Carbon capture
CO₂, H₂O, Compost

End-of-life treatments
Processing

Standardization

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Consumer goods
- Broad diversity of applications and requirements

Bioplastics
- Premium price
- Need for application technology

Polymer-grade bio-monomers

Polymerization

Recycling
Sulzer’s role in bio-polyesters
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Biomass
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Bio-precursors, e.g. Cellulose, starch, sugars, oils
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- Catalysis
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Linear bio-compounds
- Purification
- Specific to feedstock and impurities
- High quality required
- No commodity goods

Synthesis grade, linear bio-compounds
- SulCYC™
- High quality required
- No commodity goods

Consumer goods
- Processing
- Recycling

Bioplastics
- Premium price
- Need for application technology

Polymer-grade bio-monomers
- SulROP™
- High quality required
- No commodity goods

Carbon capture
- CO₂, H₂O, Compost
What’s next after PLA?

Developing a portfolio of novel bio-polyesters using our technology platforms

Bio-based linear species → SulCYC™ → Cyclic compounds → SulROP™
Swift scale-up of novel bio-polyesters

We bring technologies from lab scale to industrialization

- Lab research
- Analytical characterization
- Piloting and scale-up
- Technology licensing

Capabilities from lab research to pilot engineering and commercial plant design in Switzerland
Overall summary of bio-(co)polymers properties

**MECHANICAL PROPERTIES**

- Tensile strength
- Flexural modulus
- Impact resistance
- Young modulus
- Elongation at break

**THERMAL PROPERTIES**

- Glass transition temperature
- Decomposition temperature
- Melting temperature
- Biodegradability
- Heat deflection temperature

*All values were normalized based on their actual data to a maximum score of 10
Conclusions and Outlook

Following the strong PLA market growth, we will continue to offer tailored and licensing solutions:

- **NOVEL bio-copolyesters** with tailored properties
- **NEXT generation processes** for bio-copolymers
- **NEW applications and formulations**
Thank you!

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