Bio-Based Chemical Feedstocks

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Discussion Topics

- Definition
- Common Myths
- Three Approaches to Bio-Based Materials
- Recent Commercial Successes
- New/Old Developments
- Conclusions
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**BIO-BASED CHEMICAL FEEDSTOCKS**

- **Definition**
  - Bio-Based is defined as a product that has been made from a biological (living) or renewable source (i.e. corn, sugar cane, cellulosics, vegetable oils)

- **Bio-Based Products use New Carbon vs Old**

  ![Diagram showing the cycle of carbon from fossil fuels, biomass and bio-organics, with time frames of months to years for bio-chemical processes and >10^6 years for fossil fuels]

  Source: Tecnon OrbiChem
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**BIO-BASED CHEMICAL FEEDSTOCKS**

- **SUGARS**  
  - Glucose  
  - Fructose  
  - Xylose  
  - Arabinose  
  - Lactose  
  - Sucrose  
  - Starch

- **C2**  
  - Ethanol  
  - Ethylene Glycol  
  - Acetic Acid

- **C3**  
  - Glycerol  
  - Lactic Acid  
  - 3-Hydroxy Propionic Acid

- **C4**  
  - 1,4 Diacids (Succinic, Fumaric, Malic Acid)  
  - Butanol  
  - 1,4 Butanediol

- **C5**  
  - Furfural  
  - Levulinic Acid  
  - Itaconic Acid  
  - Xylitol

- **C6**  
  - Adipic Acid  
  - Glucaric Acid  
  - Lysine
  - Sorbitol  
  - 2,5 Furan Dicarboxylic Acid
  - Farnesene  
  - Polysaccharides
  - Polyhydroxyalkanoate (PHA)

**Source:** US Department of Energy, Tecnon OrbiChem
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COMMON MYTHS

• Bio-based materials always have a lower carbon footprint
• Bio-based chemicals and polymers are a recent development
• Bio-based materials compete with food supply and consume needed resources
• Bio-based products will require lengthy development
• Consumers will accept lower performance and significantly higher prices for Bio-based products

Source: Tecnon OrbiChem
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THREE APPROACHES TO BIO-BASED MATERIALS

1. Build on Naturally Occurring Materials
   • Rayon fibre, Cellophane film – from wood pulp, done for over 100 years. Using eucalyptus trees, the yield per hectare is 10 times that of cotton
   • Glycerin and fatty acids – from vegetable oils
   • Polylactic acid (PLA) resins from lactic acid
   • Cellulose acetate, nitrate – from cellulose

2. Develop Bio-Based Routes to Existing Intermediates
   • Bio-based processes to make MEG, paraxylene, adipic acid, butadiene, caprolactam etc. are being developed; they are in varying stages of advancement - ‘drop in’ chemicals

3. Develop New Polymers/Fibres
   • Completely new bio-based polymer products that demonstrate similar or improved properties compared to existing commercial oil-base products.

Source: Tecnon OrbiChem
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COMMERCIAL SUCCESS (INTERMEDIATES)

- **1,3 PDO**
  - DuPont Tate & Lyle ferments corn sugar to produce 1,3 PDO in Loudon, Tenn.
  - Reports of glycerol-based PDO in China

- **BUTANOL**
  - Corn-based n-butanol already produced in China - Cathay Industrial Biotech, Laihe Rockley, small firms
  - Gevo started corn-based isobutanol shipments this year

- **SUCCINIC ACID**
  - Reverdia and Myriant plants running, BioAmber and Succinity to follow early 2014

- **GLYCOLS**
  - ADM, Oleon producing PG using glycerol (and sorbitol for ADM) as feedstock. HK-based Global Bio-Chem produces PG using corn glucose
  - Greencol Taiwan, India Glycols producing bio-MEG from sugarcane-based ethanol

- **EPICHLOROHYDRIN**
  - Vinythai produces glycerol-based ECH in Thailand, plans another 100KTY facility in China
  - Reports of Chinese plans for bio-ECH

- **FARNESENE**
  - Start of Amyris’ 50m liters/year sugarcane-based fermentation plant in Brazil this year
  - Building block for lubricants, base oil, isoprene, squalene, F&F ingredients

- **POLYAMIDES**
  - Brand owners such as Nike, Puma, Gucci are using castor oil-based PA10 and PA11
  - Bio-based PA producers include Arkema, Evonik, BASF, Solvay, DSM, Radici Group, DuPont, EMS-Chemie

Source: Tecnon OrbiChem
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COMMERCIAL SUCCESS (BIOPOLYMER)

Sorona® PTT

PlantBottle® PET

Ingeo® PLA

I’m Green® PE

BiOH® Polyol

Mirel® PHA

Source: Tecnon OrbiChem
Global BioPlastics Production Capacity 2011

- Others: 0.4%
- Bio-PA: 1.6%
- Bio-PE: 17.2%
- Bio-PET 30: 38.9%
- PLA: 16.1%
- Biodegradable Polysters: 10%
- Biodegradable Starch Blends: 11.3%
- Regenerated Cellulose*: 2.4%
- PHA: 1.6%
- Others: 0.5%

Total: 1,161,200 metric tonnes

Biobased/non-biodegradable: 58.1%
Biodegradable: 41.9%

Source: European Bioplastics, Institute for Bioplastics and Biocomposites (Oct. 2012)
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COMING SOON (DROP-IN INTERMEDIATES)

• BENZENE, TOLUENE, XYLENE (BTX)
  o Anellotech’s Bio-BTX, Virent’s BioFormPX
  o Paraxylene from Gevo’s isobutanol

• ADIPIC ACID
  o Verdezyne, Rennovia, DSM, Genomatica, BioAmber

• ACRYLIC ACID
  o OPX Biotechnologies/Dow Chemical, Myriant, Novozyme/Cargill/BASF, ADM, Novomer, Metabolix

• BUTANEDIOL
  o Genomatica, Myriant, BioAmber, LanzaTech

• RUBBER FEEDSTOCK – BUTADIENE, ISOPRENE, ISOBUTENE
  o Butadiene – Amyris/Kuraray, LanzaTech/Invista, Versalis/Genomatica, Global Bioenergies/Synthos, Cobalt Biotechnologies
  o Isoprene – Amyris/Michelin, Ajinomoto/Bridgestone, DuPont/Goodyear, Aemetis, Glycos Biotechnologies
  o Isobutylene - Global Bioenergies/LanzaTech, Gevo/Lanxess

Source: Tecnon OrbiChem
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UNDER DEVELOPMENT (NEW FEEDSTOCK)

- **2,5 FDCA (Furan Dicarboxylic Acid)**
  - FDCA + MEG = Polyethylene Furanate (PEF) as alternative to PET
  - Nylons and Aramids using adipic acid can be reformulated with FDCA

- **Carbon Monoxide/Carbon Dioxide**
  - \( \text{CO}_2 + \text{Propylene Oxide} = \text{Polypropylene carbonate (PPC)} \)
  - \( \text{CO}_2 + \text{Ethylene Oxide} = \text{Polyethylene carbonate (PEC)} \)
  - \( \text{CO}_2 \rightarrow \text{Polyether Polycarbonate Polyols (PPP)} \)
  - \( \text{CO} + \text{Ethylene Oxide} = \text{Propiolactone} \)
  - \( \text{CO}/\text{CO}_2 \rightarrow \text{C}_2\text{-C}_5 \text{ products (via GTL and fermentation)} \)

- **Levulinic Acid**
  - \( \text{LA} \rightarrow \beta\text{-acetacrylic acid} = \text{New acrylate polymers} \)
  - \( \text{LA} \rightarrow \text{Diphenolic acid} = \text{Replacement for Bisphenol-A} \)
  - \( \text{LA} \rightarrow 1,4\text{-pentanediol} = \text{New polyesters} \)
  - \( \text{LA-derived lactones for solvents application} \)

Source: Tecnon OrbiChem
CONCLUSIONS

- Companies will come under increasing pressure to demonstrate that they are improving their environmental awareness, by reducing their carbon footprint and raising the sustainability of their operations.
- Many companies around the world are working to develop bio-based monomers, using both biological and chemical methods of converting natural raw materials.
- Quickest commercialisation and largest opportunities will likely involve ‘drop in’ monomers/polymers that take advantage of existing industry infrastructure.
- Commercial success has often involved partnering as different technologies and skill sets are needed to come together.

Source: Tecnon OrbiChem
• Companies introducing bio-based monomers will ultimately have to demonstrate:
  o That their operations do not reduce the food supply
  o That a direct replacement (‘drop in’) monomer costs the same as its synthetic equivalent – or maybe 10-20% more if it allows the end user to boast of his environmental friendliness
  o That a new monomer gives rise to a new polymer that has as good or better performance than existing polymers
• Existing polymers/fibres (PET, PA6,6 etc) made with bio-based monomers will be greatly welcomed by the textile and packaging industry, provided there is no loss of performance due to impurities

Source: Tecnon OrbiChem
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