Bio-Based Chemicals Overview

2019 PCA International Conference
Vancouver, B.C., Canada, 23 - 24 September 2019

Doris de Guzman
Senior Consultant – Biomaterials
Doris.de-guzman@orbichem.com
BIO-MATERIALS & INTERMEDIATES

A monthly publication reporting market trends, pricing, and feedstock for Bio-based chemicals and their Petrochemicals counterpart

Started in 2007 & Inspired by an unwavering belief that we can and will do better

www.greenchemicalsblog.com
Value additions of Bio-based Industry to US Economy

- Textiles: $364bn
- Forest Products: $22bn
- Bio-based Chemicals: $106bn
- Enzymes: $35bn
- Agriculture and Forestry: $3.5bn (NA)
- Biorefining: $506m
- Bioplastic bottles and packaging: $1.11bn

Source: USDA, PCA
Value additions of Bio-based Industry to EU Economy

- Textiles: €47bn
- Wood Products, Furniture: €56bn
- Bio-based chemicals, pharma, plastics and rubber: €106bn
- Forestry: €174bn
- Agriculture: €174bn
- Food, Beverages, Tobacco: €233bn
- Paper: €46bn

Source: Road-To-Bio Project, PCA
BIOECONOMY DRIVERS

• Chemical/Petrochemical companies aligning themselves with scientific community’s climate change stance
• Plastic pollution pressures will continue
• Production becoming regional reflecting trade wars and other barriers to entry
• Consumer increase in appetite for ‘naturals,’ ‘holistic,’ ‘sustainable stories’
• Synthetic Biology investments
• Zero-waste approach and use of waste-based feedstock
• Growing government support of circular Bioeconomy
  • EU, Canada, Australia, Thailand
  • China’s drive for environmental regulations
US PETROCHEMICALS, NATURAL GAS, CRUDE OIL & SUGAR PRICES 2014-2019

Source: Tecnon OrbiChem, *Petrochemwire
EUROPE PETROCHEMICALS, CRUDE OIL & SUGAR PRICES 2014-2019

Source: Tecnon OrbiChem
ASIA PETROCHEMICALS, CRUDE OIL & SUGAR PRICES 2014-2019

Dollars per Ton

Source: Tecnon OrbiChem
LOW OIL PRICE DRIVING NEW BIO-REALITIES

➢ Companies are refocusing on higher-profit, low-volume specialty markets
  ▪ Food and Nutrition, Flavors and Fragrances
  ▪ Pharmaceuticals, fine chemicals
  ▪ Higher R&D-based chemicals: lubricants, surfactants, engineering resins, coatings, solvents, high-tech materials (e.g. biomedical)
  ▪ Animal feed and nutrition

➢ Novel molecules gaining more interests vs drop-ins

➢ Bio-based commodity chemicals will continue as niche markets

➢ New polymers and applications will have to undergo lengthy testing before they will be accepted
THE BIO-MONOMER REALITIES

➢ Success in bio-based monomers:
  ▪ Monomers with competitive pricing or even better performance than traditional materials
  ▪ Monomers that offer novel properties
  ▪ Regulation-based demand

➢ Improved properties might have short-term price implications.

➢ Companies introducing bio-based chemicals require:
  ▪ That their operations do not reduce the food supply
  ▪ That a direct replacement ("drop in") costs the same as its synthetic equivalent -- or maybe slightly more if it allows end users to boast about their environmental and sustainability initiatives
BIO-POLYURETHANES INTERMEDIATES

Source: Wageningen UR, Tecnon OrbiChem
BIO-BASED PU INTERMEDIATES: POLYOLS

➢ Maturing vegetable oil-based polyester polyols market
  ▪ Improvements in performance
  ▪ Still possess premiums
  ▪ Biobased Technologies, Cargill, BASF, Dow Chemical, Huntsman, Emery Oleochemicals, Lubrizol, PolyLabs, Vithal Polyols Pvt

➢ Polyether polyols based on sorbitol and bio-based diols

➢ Isosorbide-based polycarbonate polyol (Mitsubishi Chemical)
  ▪ Isosorbide sourced from Roquette

➢ Pentaerythritol polyol (Perstorp’s Voxtar™ based on bio-acetaldehyde)

➢ CO2-based PPC/PEC polyols
  ▪ High potential but long R&D due to specialized formulations
  ▪ Pilot/Demo production
  ▪ Can also be bio-based using renewable-based EO
  ▪ Covestro, Aramco, Jinlong CAS Chemical, Empower, Econic, Norner Verdandi, BASF, Evonik
BIO-BASED PU INTERMEDIATES: DIACIDS/DIOLS

➢ Growing interests in alternative bio-based diacids/diols intermediates
➢ Can be priced competitive, depending on applications, even if value addition in performance involve premiums

➢ Diacids
  ▪ Adipic Acid – lower-cost petro-AA prevents bio-AA commercialization
  ▪ Succinic Acid – further application R&D needed
  ▪ Levulinic Acid – few producers, further application R&D needed
  ▪ Glucaric Acid – intermediate for bio-AA production
  ▪ Furandicarboxylic Acid – no commercial production as of yet
  ▪ Long-chain Diacids – commercial DDDA, C18 OCDA
  ▪ Dimer Acids – well-established market w/ some industry restructuring

➢ Diols
  ▪ 1,3 Propanediol – sugar-based or glycerol-based
  ▪ 1,4 Butanediol – Novamont production, Genomatica technology
  ▪ MEG and MPG – few producers; various ongoing pilot projects
  ▪ 1,3 Butylene Glycol – currently targets cosmetics applications
LEVULINIC ACID AS A BUILDING BLOCK
BIO-BASED PU INTERMEDIATES: ISOCYANATES

- Limited developments in drop-in bio-based isocyanates

  **Hexamethylene diisocyanate**
  - Drop-in sugar-based HMDA by Genomatica
  - HMDA via fructose-based 1,6 hexanediol

  **Pentamethylene diisocyanate**
  - Based on 1,5 PDA produced by Cathay Industrial Biotech
  - BASF, Mitsui Chemicals, Covestro in PU applications

  **Aniline** – production of intermediate using sugar and microorganism
  - Covestro leading R&D
  - Target large industrial scale by mid-2020s

  **Malonic Acid** – could replace adipic acid or succinic acid
  - Cross-linker that could replace/diminish reliance on isocyanates
  - Lygos, DMC Bio, Sirrus, BASF

- Development of non-isocyanate PU based on vegetable oils
- Diisocyanates from succinic anhydride and isosorbide/isomannide
VALUE-CHAIN OF BIO-BASED EPOXY RESINS

Co-Reactants
- Bisphenol A
- Bisphenol F
- Other phenolics

Epoxy Resins

Epichlorohydrin

Reactive Diluents

Other Co-Reactants

Curing Agents

Source: AGC Chemicals Europe
BIO-BASED EPOXIES & INTERMEDIATES

 Gibichlorohydrin – commercialized glycerol-based ECH
  ▪ Same price as propylene-based ECH

Phenolic/Cyclic alternatives - mostly still at R&D stages
  ▪ Novolac phenolic resins can be made from bio-based formaldehyde and phenolic lignin
    ▪ High-phenolic lignins as alternative to benzene-based phenol
    ▪ Formaldehyde using bio-based methanol feedstock
    ▪ 5-HMF in formaldehyde replacement
  ▪ Soy-based reactive oligomer technology can replace BPA
  ▪ Lignin-based bisguiaicol F to replace BPA
  ▪ Rosin diglycidyl ether
  ▪ FDCA-based diglycidyl ester
  ▪ Diglycidyl ethers of isosorbide
BIO-BASED EPOXIES & INTERMEDIATES

➢ Co-reactants for aliphatic reactive diluents
  ▪ C12-14 diglycidyl ether using C12-14 fatty alcohol co-reactant
  ▪ 1,4 BDO diglycidyl ether using bio-based 1,4 BDO co-reactant
  ▪ Cardanol glycidyl ether using cashew nut shell liquid (CNSL)

➢ Curing agents
  ▪ Bio-based phenalkamines using CNSL
  ▪ C36 fatty acid polyamides using dimerized TOFA
  ▪ CO₂-based ammonia as co-reactant for amines

➢ Bio-based solvents used in epoxies
  ▪ Aromatics – direct production, bio-naphtha
  ▪ Ketones – acetone from fermentation or bio-benzene; MIBK from bio-acetone
  ▪ Ethylene Glycol Ethers –n-butanol or ethanol + bio-EO
OTHER NOTEWORTHY BIO-BASED BUILDING BLOCKS

➢ Terpenes
  ▪ Growing use of fermentation technologies and synthetic biology
  ▪ Unlimited production using sugar and microorganism
  ▪ Applications in adhesives, fragrances, pest control, cosmetics, etc.

➢ Lactides – development of lactide-based adhesives

➢ Acrylics/Acrylates
  ▪ Bio-based acrylic acid – stalled R&D due to low petro price
  ▪ Bio-based MMA
    ▪ Slow but growing R&D. No commercial production
    ▪ Lucite using building blocks (bio-acetone, bio-ethylene, bio-methanol, etc.) or a novel one-step fermentation route (undisclosed)
    ▪ Itaconic acid route; Isobutene/Isobutanol route; Isobutyric acid route
    ▪ Evonik markets partially bio-based VISIONER®Terra methacrylate monomers incorporating feedstock such as camphene and natural oils

OTHER NOTEWORTHY BIO-BASED BUILDING BLOCKS
NEW FEEDSTOCK FOCUS:
BIO-NAPHTHA, BIOGAS, BIO-METHANOL, CO₂

➢ Renewable diesel producers looking to diversify downstream
  ▪ Production of bio-naphtha, bio-propane
  ▪ High investment requirements
➢ Naphtha from CTO production - UPM
➢ Naphtha/Methanol from MSW feedstock (syngas to syncrude)
➢ Continued activities in mass balance approach
  ➢ Use of bio-naphtha, bio-methanol, biogas
  ➢ BASF, SABIC, Dow, DuPont, Perstorp, Neste
➢ Bio-oil from pyrolytic plastic wastes
➢ Increase R&D/commercialization of CO₂-based chemicals
  ▪ Renewable hydrogen requirements for CCUs
NEW FEEDSTOCK FOCUS: LIGNIN

- Pulp and Paper companies lead R&D
  - UPM, Stora Enso, Borregaard, Domtar, West Fraser, Metsa Fibre Oy
  - Around 55m tpa lignin produced as side product. 1m tons reaches chemicals market
  - Lignin burned for power and heat
- Lignin from Cellulosic Ethanol Production
- Lignin bio-composites
- Vanillin from Lignin
- Lignin-based aromatics
  - Phenol
  - BTX
  - Bio-oils
NEW FEEDSTOCK FOCUS:
CELLULOSIC SUGARS AND NON-FOOD LIPIDS

• Sugars from waste agriculture crops
  ➢ Corncobs/stalks, Sugar Bagasse, Wood Chips
  ➢ No commercial markets
  ➢ Low traditional sugar prices

• Industrial crops R&D
  ➢ Castor, Camelina, Guayule
  ➢ Years of field crop testing

• Algae R&D
  ➢ Difficulty in commercialization; low yield; high expenses
  ➢ Focus on fuels

• Waste fats and cooking oils
  ➢ Becoming more expensive compared to plant food oils
www.orbicchem.com
Doris.de-guzman@orbicchem.com