Novasep Process:
Advanced Purification Technologies for Bio-Based Chemicals

Pacific Rim – Industrial Biotechnology and Bioenergy

Vancouver, BC
October 12th, 2012
Producing Bio-Based Chemicals

The challenge!

Novasep Process: Advanced Purification Technologies for Bio Based Chemicals
Another View of the Challenge

The challenge!!
Cracking Biomass

Pre-Treatment → Extraction Separation

- C6 Sugars
- C5 Sugars
- Lignin

Novasep Process: Advanced Purification Technologies for Bio Based Chemicals
How to Get Pure Fractions?

- **Pre-Treatment**
- **Extraction Separation**
- **Purification**

**Impurities**

- **C5 Sugars**
- **C6 Sugars**
- **Lignin**

Novasep Process: Advanced Purification Technologies for Bio Based Chemicals
Producing Bio-Based Chemicals

C6 Sugars → Fermentation → Chemical Catalysis → Enzymatic Catalysis → Bio-Based Chemical

What you think you will get?
What you really get is...

- End product
- Feed material
- Side products
- Salts
- Proteins
- Biomass
Producing Pure Chemicals

What it takes to get pure product!

- Feed material
- Side products
- Salts
- Proteins
- Biomass
Solving the Challenge

Advanced Purification Technologies

- Efficient
- Cost Effective
- Reliable
- Scalable
Our Markets

Biopharma
- Recombinant Proteins
- Vaccines
- mAbs - ADC
- Blood Fractionation
- Biomass Extracts
- Cell Therapy

Food Ingredients
- Sugar
- Starch
- Milk

Functional Ingredients
- Polyphenols
- Anthocyanes
- FOS
- Sweeteners

Bio-Industries

White Biotechnology
- Organic Acids
- Aminoacids
- Antibiotics
- Vitamins
2011 revenues: $400 M
1200 employees, 200 in R&D

Over **100 R&D projects** per year
Over **100 active molecules** produced per year
Over **2,000 purification systems** installed worldwide
Over **650 customers** served worldwide
Technologies

An Unparalleled Breadth of Key Unit Operations
An Unparalleled Breadth of Key Unit Operations

- Continuous chromatography
  - Applexion® SSMB
  - Separation of fractions
  - Purification

- Evaporation/Crystallization
  - Plate or tubular
  - Multiple effect
  - MVR

- Electrodialysis
  - Demineralization
  - Salt Conversion

- Membrane filtration
  - Organic & Ceramic
  - Clarification
  - Concentration

- Adsorption/IEX
  - Salt conversion
  - Demineralization
  - Decolorization
  - Batch or Continuous

Biobased Chemicals Purification

- Continuous chromatography
- Membrane filtration
- Evaporation/Crystallization
- Electrodialysis
- Adsorption/IEX

Purity
Kerasep® Filtration Membranes

- Ceramic membranes: Kerasep®
- Micro and Ultrafiltration
- Applications:
  - Clarification of fermentation broth
  - Purification and concentration of enzymes

- Feed: 1550 m³/day – 240 g/L
- Target recovery: 99%
- Carousel design with 14 skids
- 2 CIP systems
- Up to 6 years lifetime guarantee
- Installed Base > 100 000 m²
Ion Exchange and Adsorption

- Batch and continuous ion exchange
- Adsorption on resins and activated carbon
- Applications: decolorization, desalting, purification and salt conversion

Low consumption of:
- Chemicals
- Water
Electrodialysis

- ED: transport salts from one solution through ion exchange membranes to another solution by way of an electrical current
- Applications: desalting and purification of sugars, organic acids

- High desalting efficiency
- No effluents generation
- No chemicals consumption
Evaporation & Crystallization

- Multiple effect, MVR or TVR
- Plate or tubular evaporators
- FF and FC
- Applications:
  - Citric acid
  - Mineral salts
  - Sugars
  - Vinasses

- High energy efficiency
- Thermal integration in your plant
- Experience with scaling products
Applexion® SSMB Chromatography

- **Affinity chromatography:**
  - Xylose / Arabinose / Glucose separation
  - Glucose / Mannose
  - Polyols

- **Ion exclusion:**
  - Sugar and salt separation
  - Polyol demineralization

- **High purity fractions**
- **Low water usage**
- **No chemical consumption**
Chromatography

The Lab HPLC Equipment!
Applexion® SSMB Chromatography

The Industrial Process!

Commonly used for:
- Glucose
- Fructose
- Vinasses / Stillages
- Citric acid
50 pilots available in Europe, USA and China
20 processes in Industrial Biotech developed each year
Performance guarantee

Technology + Know-How + Process Development =

Your Process Performance Guaranteed!
CASE STUDY 1: Succinic Acid Purification

- Succinic acid as a key chemical intermediate
- Customer: JV ARD – BioAmber
- Process development work started in 2004
  - Technology Screening
  - Process Simulation
  - Process integration
  - Piloting work
- 1st industrial Bio Succinic Acid plant worldwide started in 2009, with Capacity 3,000 t/year
- Other studies on-going (more than 6 routes studied)
CASE STUDY 1: Succinic Acid Purification

- Clarification by Kerasep\textsuperscript{®} membrane filtration

- 2 different processes, depending on local conditions:
  - Applexion\textsuperscript{®} CIEX
  - Novasep – Mega\textsuperscript{®} Electrodialysis
CASE STUDY 2: Chemical Polyol Purification

- Customer: confidential
- Molecule: chemical polyol, confidential
- 99% purity, 99% recovery
- Process development work started in 2007
  - Technology Screening
  - Process simulation
  - Process integration
  - Piloting work
- 1st industrial plant started in 2008
- Expansion to increase the throughput in 2011
- Further expansion of certain unit operations in 2013
CASE STUDY 2: Chemical Polyol Purification

- Separation of chemical polyol and salts by Applexion® SSMB, on ion exclusion principle
- Concentration by reverse osmosis
- Separation of chemical polyol and sugar by Applexion® SSMB, on affinity principle

![Graph showing concentration of salts, glucose, and polyol over columns](image)
Membranes, Chromatography, IEX, Electrodialysis

= 

**VERY Efficient, cost-effective, reliable and scalable** technologies
Allowing to reach **high degrees of purity**
& relying on the use of various physio-chemical properties:
  - pKa
  - Molar mass
  - Hydrogen bounds
  - Solvatation size
  - Isoelectric point
  - Hydrophobic/hydrophilic interactions
  - Polar/non polar interactions
  - Molecular Geometry configuration

Novasep Process designs **optimized and integrated** process routes, 
selected among competitive technologies depending on local conditions, 
and applied industrially to obtain products which market prices typically < $3/kg
Proven Results...

- Lactic Acid
- Succinic acid
- Citric Acid
- Gluconic acid
- Itaconic acid
- Glucose
- Mannose
- Arabinose
- Oligosaccharides
- Sorbitol
- MSG
- Mannitol
- 1,4 BDO
- 1,3 PDO
- Fructose
- IMP
- Threonin
- Xylose
- GMP
- Glucaric acid
Here’s to your success!

John.Bhatt@novasep.com