Optimization of Whey and Whey Derivatives Demineralisation Process

Whey Technology and Utilisation Conference June 12th 2013
Novasep designs and develops processes and purification technologies, and also provides industrial systems with guaranteed performance for the purification and production of:

- Food ingredients
- Functional Ingredients
- Bio-Industries
- Biopharma
Our Markets

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

Food Ingredients
- Sugar
- Starch
- Milk ingredients
  - Demin Whey
  - Lactose

Functional Ingredients
- Polyphenols
- Anthocyanes
- FOS
- Sweeteners
- Omega 3
- Stevia

Bio-Industries
- White Biotechnology
- Organic Acids
- Aminoacids
- Antibiotics
- Vitamins
- Bio-based Chemicals
Combined Technologies

Synthesis and Biosynthesis

- Chiral chemistry
- Hazardous chemistry
- Multi-step synthesis
- Continuous chromatography
- Crystallization
- Ion exchange

Purification

- Membrane filtration
- Evaporation Distillation
- Electrodialysis
- Batch chromatography
- Chemistry of highly potent substances
- Feedstock extraction
- Fermentation
- Cell culture

Corporate Presentation – 03/2013
Over 650 customers served worldwide
Over 100 R&D projects per year
Over 100 different active molecules produced per year
Over 2,000 purification systems installed worldwide

300 M€ turnover
1200 people, 200 in R&D
13 sites
# Dairy Ingredients
## Purification of Minor Components

### Applications of Novasep Purification Technologies for the Production of Various Dairy Ingredients

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<th>Milk Products</th>
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<th>UF</th>
<th>NF</th>
<th>IEX</th>
<th>DK</th>
<th>SSMB</th>
<th>LPLC</th>
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What products Can be obtained from Whey

• Whey powder
• Demineralised whey D30/D50/D70/D90
• WPC 35
• WPC80 and WPI
• Whey permeate
• Lactose and derivatives
• Native and denatured whey proteins
• Fractions with enriched proteins
• Bioactive peptides
• Oligosaccharides
• etc
Lactose Production
Increased Yield and Quality
Applications

• D30 – D70 Food Ingredients

• D70/D90 Infant Formula
Demineralised Whey D90 Producers

- Nestlé
- Danone
- Friesland Foods Domo
- Euroserum
- Lactalis
“Baby milk rationed in UK over China export fear”
Demand for foreign-made baby milk in China is strong after contaminated baby formula killed six infants in 2008.
Retailers in the UK are rationing sales of powdered baby milk because of a surge in demand in China.
Danone, the manufacturer of Aptamil and Cow and Gate baby milk powder, said most supermarkets were introducing a restriction of two cans per customer. It said the limit was to prevent some individuals from bulk-buying baby milk for "unofficial exports". Retailers were also capping sales of Nestle's baby milk powder.
Europe Milk Quota System will be abolished in 2015.
Typical Sweet vs. Demineralized Whey composition

Sweet Whey

- Water: 93.36%
- Lactose: 4.95%
- Whey proteins: 0.80%
- NPN: 0.20%
- Ash: 0.10%
- Fat: 0.02%
- Lactate, citrate: 0.57%

D50 Whey

- Water: 80.00%
- Lactose: 11.50%
- Whey proteins: 4.00%
- NPN: 1.00%
- Ash: 3.43%
- Lactate, citrate: 0.05%

D70 Whey

- Water: 82.00%
- Lactose: 11.50%
- Whey proteins: 2.50%
- NPN: 1.00%
- Ash: 2.95%
- Lactate, citrate: 0.03%

D90 Whey

- Water: 84.00%
- Lactose: 11.50%
- Whey proteins: 1.00%
- NPN: 0.50%
- Ash: 2.96%
- Lactate, citrate: 0.02%

Sweet Whey DS

- Water: 74.55%
- Lactose: 12.05%
- Whey proteins: 3.01%
- NPN: 8.58%
- Ash: 1.51%
- Lactate, citrate: 0.30%

D70 Whey DS

- Water: 82.00%
- Lactose: 11.50%
- Whey proteins: 2.50%
- NPN: 1.00%
- Ash: 2.95%
- Lactate, citrate: 0.03%

D90 Whey DS

- Water: 84.00%
- Lactose: 11.50%
- Whey proteins: 1.00%
- NPN: 0.50%
- Ash: 2.96%
- Lactate, citrate: 0.02%
Sweet Whey
mineral composition

Combination of monovalent and divalent ions

Sweet Whey
Typical ash composition in ppm/TS

- Na$: 30889 ppm
- K$: 6024 ppm
- Ca$: 26250 ppm
- Mg$: 15437 ppm
- PO₄$: 6642 ppm
- Cl$: 1551 ppm
- SO₄$: 1551 ppm

Legend:
- Na$: light blue
- K$: red
- Ca$: dark purple
- Mg$: light purple
- PO₄$: dark red
- Cl$: yellow
- SO₄$: blue
Novasep separation technologies used industrially for whey demineralization:

- Cross-Flow Nanofiltration
- Electrodialysis
- Ion-Exchange
Dairy Industry

Demineralization of Whey or Permeate

An optimized demineralization process provided by Novasep

- Combination of NF+ED+IEX:
  - Highest Flexibility
  - Modular System
  - Lowest Costs

- A Question of Costs:
  - CAPEX + OPEX for NF
  - CAPEX + OPEX for ED
  - CAPEX + OPEX for IEX
Optimized set-up of Novasep/Mega lines with 1xEDR-6/250
Membrane Technologies for Whey particles of different
Whey demineralization technologies

Cross-Flow Nanofiltration
- Continuous Process 21 Hrs + CIP

- Removal of 30% of the minerals in NF permeate, mostly monovalent minerals

- Ideally suited for initial concentration (water removal) of liquid whey from 6 to 18-22%TS

![Diagram of whey demineralization process]

- Cl⁻, Na⁺, H₂O, Lactose, Remain Ca²⁺ and PO₄³⁻
- Retentate: Concentrated lactose and divalent salts
- Permeate: Water and monovalent salts
Demineralization by Cross-Flow Nanofiltration

- Whey feed to NF 6%TS
- Flux declining quickly when NF retentate reaching 21-22%TS
- Demineralization rate limited to 30-35%
Demineralization by Cross-Flow Nanofiltration

- NF is a monovalent demineralization process, because most ions transferred to NF permeate are monovalent: Cl, K, Na
- NF retentate is enriched into divalent ions: Ca, Mg, PO4, SO4
**Demineralization by Cross-Flow Nanofiltration**

- Most effective demineralization process, only consuming electricity, NF membranes replacement, and small quantities of CIP water and chemicals
- Capital cost is effective, as the NF can be designed from small to large capacities, by varying the number of stages on a single NF skid.
- Loss of whey proteins into NF permeate is nearly 0
- Loss of lactose into NF permeate limited to about 1%

**Nanofiltration can only demineralize 25-35%**

**Mostly a monovalent demineralization process**
Whey Demineralization by Electrodialysis Principle
Homogeneous Vs Heterogeneous membranes

**Mega Membrane material**

**Heterogeneous**

*Mega* ED membranes are ion-exchange heterogeneous membranes have tangible benefits compared with traditional and homogeneous membranes

- Heterogeneous membranes, polymer mixed with milled ion exchange resin for membrane conductivity
- Open structure with large channels for small monovalent and large diavalent ions,
- More uniform ions transfer rates compared to homogeneous membranes
• Homogeneous ED membranes N° 1 and 2 traditionally used for whey demineralization have good transfer of monovalent ions, but poor transfer of divalent ions - Heterogeneous membranes manufactured by MEGA have more uniform ions transfer rates.
Whey demineralization technologies

Electrodialysis

- Works best on pre-concentrated whey concentrated
- Flexible demineralization rate D50, D70, D90
- Chemical minimal usage, limited to ED membranes cleaning
- Electrodialysis process running at 15C to ensure microbiological stability of whey
Electrodialysis

- Removal of mostly monovalent, and some divalent ions by transfer from whey solution into brine solution
- Nearly no effect on whey concentration
- More efficient at high conductivity, pre-concentrated whey 20-22%TS is optimum
Whey demineralization technologies

Electrodialysis

- Batch Process - working cycle time of ED unit: up to 20 hours per day, CIP cycle time: only 4 hours
- 4 years membrane lifetime warranty and post-warranty services
- Easy Maintenance – Over Head removal of membrane stacks
Demineralisation
by Electrodialysis
Demineralisation by Electrodialysis

- Electrodialysis provides intermediate to higher levels of demineralization, only consuming electricity, membranes replacement and small quantities of CIP water and chemicals
- Capital cost is effective, if a small number of ED skids is used at full demin capacity
- Loss of whey proteins into Brine Concentrate is in the range 1-2%
- Loss of lactose into Brine Concentrate limited to about 2%

- Production of brine concentrate saturated with minerals
Demineralisation by Ion Exchange

- Applicable to all type of whey: dilute, concentrated, pre-demineralized
- Most efficient removal of divalent ions
- Ideal for high demineralization rates and compliance with specific D90 ionic profiles

Sweet whey $\rightarrow$ HCl $\rightarrow$ H$^+$ $\downarrow$ K$^+$, Na$^+$, Ca$^{++}$ $\rightarrow$ Demineralised sweet whey

Sweet whey $\rightarrow$ NaOH $\rightarrow$ OH$^-$ $\downarrow$ PO$_4$$^-$$^-$, Cl$^-$, Organics

Flowchart shows the process of demineralisation with HCl and NaOH leading to a decrease in mineral content in the whey.
Ion Exchange Principle

PO₄⁻
Cl⁻
Organics

H⁺
K⁺
Na⁺
Ca²⁺

WATER

Negatively Charged Analyte [Anion]
Attracted to Positive Surface

Anion Exchanger
Stationary-phase Particle

OH⁻

Positively Charged Analyte [Cation]
Attracted to Negative Surface

Cation Exchanger
Stationary-phase Particle

OH⁻

H⁺
Ion Exchange Resin Process

Sweet whey → Demineralised sweet whey

\[ \text{Captured on Cationic resin} \]
\[ \{ \]
\[ K^+ \quad Na^+ \quad Ca^{++} \]
\[ \text{Captured on Anionic resin} \]
\[ \{ \]
\[ \text{PO}_4^{2-} \quad Cl^- \quad \text{Organics} \]
Ion Exchange Resin Regeneration

- HCl
- NaOH

- K⁺
- Na⁺
- Ca²⁺
- H⁺
- Cl⁻

- PO₄³⁻
- Cl⁻
- Organics
- OH⁻
- Na⁺
Demineralization by Ion-Exchange

- Ion-Exchange mainly used for the production of D90 demin whey,
- Can be used as a polisher, after NF, or NF + ED
- Capital cost is effective
- Loss of whey proteins vary usually around 5%
- Loss of lactose limited to about 1% during sweet-on/off operations
- Simple batch operation, fully automatic

- Resins regen consumes Acid & Base chemicals and generates effluents
Optimized whey demineralization process solutions
Whey Demineralization Novasep/Mega conclusion

Dairy Map Strategy

- Optimum CAPEX/OPEX combination.
- Design and implementation of processes adjusted to any targeted capacity for various markets (D30, D50, D70, D90)
- Multi-step processes requiring higher capital investment, but provide significant reductions in operating cost and chemicals/effluents for larger production capacities
- Conception of flexible processes allowing future capacity increase depending on market demand
Thank You for Your Attention!

anthony.lloyd@novasep.com