Enhanced electrodialysis for high degree demineralization of whey

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Head of Membrane Processes Division
Topics

1. Company brief introduction.
3. Whey demineralization technologies and product specifications.
4. Enhanced electrodialysis for whey demineralization by MEGA
   - Main suppliers of demin process
   - Difference in D90 specifications
   - Process flow diagram, requirements, main aspects
   - Equipment portfolio
   - Operational expense and warranty
   - Installed capacity
   - Key features of enhanced ED
MEGA Czech Republic - brief introduction

For more than 30 years MEGA a.s. is focused on electro-membrane separation based on own know-how. Company has started as small local ED supplier for water applications, nowadays belongs into group of 3 biggest ED suppliers worldwide. All the company activities aim to satisfy customers’ needs and are carried out with maximum respect to the environment.

MemBrain s.r.o. is a MEGA’s R&D organization, founded in 2008 to boost research activities in the field of membranes processes. With creation of new European Membranes Innovation Centre, we can offer state-of-the-art solutions for different industries always taking into account practical experience from numerous project realized by MEGA.

RALEX® is original trademark for the ion exchange membranes and membrane technologies by MEGA.

Reliable
Affordable
Long-lasting
Efficient
eXtra quality

More info at www.ralex.eu
Our capability in electrodialysis

- We continuously develop the process since 1984
- We provide feasibility study based on lab/pilot trials to confirm best process performance
- We manufacture all main components:
  - Membranes, spacers
  - Stacks
  - Equipment
- We design the ED process for different applications
- We supply the process along with necessary services and guarantee
- We care, on-site training, online monitoring and consultations are parts of MEGA Care services
Technological partnership in whey demineralization

- In 2010 companies MEGA (CR) and NOVASEP (FR) signed a technology partnership to develop whey treatment solutions for the dairy industry.

- MEGA and NOVASEP promote optimum process solutions for the dairy market by totally combining their technologies.

- Main goal of collaboration:
  - Design and implementation of demin processes adjusted to any targeted capacity for various markets (D30, D50, D70, D90)
  - Concept of flexible processes allowing future capacity increase depending on market demand
  - Optimum CAPEX/OPEX combination => DAIRY MAP TOOL
Is there future for demineralized whey product?

MARKET SURVEY
Whey Book 2014

The Global Market for Whey and Lactose Ingredients
2014-2017

August 2014

3A Business Consulting
Global demand for whey proteins 2009-17 - the market demands

- Around 250,000 MT of DWP is used for baby food
- Demand for WPC80, WPC50-79, DWP, lactose and permeate is likewise forecast to show relatively strong growth
- Global demand is forecasted to exhibit the highest annual growth for WPI
Global production across all product categories is dominated by the EU-area and North America. US in particular for WPC80 and WPI.

Developing regions mainly produce WP.

Oceania is a key region for lactose and WPC80.
Global market projections for 2013-17 - market value on the rise

The global market value of **whey ingredients** amounts to **USD bio. 9.8 by 2013**, and is forecast to reach **USD 11.7 bio. by 2017**

**WP is by far the largest volume** and value category in 2013, and this will also be the case in 2017

It is worth mentioning that **WPC80 and WPI represent less than 7% of total volume but more than 30% of global market value** in 2013

### Whey products market size by volume ('000 MT), value and CAGR 2013-2017

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market volume, '000 MT</td>
<td>4,082</td>
<td>4,538</td>
</tr>
<tr>
<td>Market value, USD bio</td>
<td>9,824</td>
<td>11,694</td>
</tr>
</tbody>
</table>

Note: Bubble size indicates volume in 2013
Global market projections for 2013-17 - strongest growth in permeate powder

- The **market value for lactose and permeate of approx. USD bio. 2.3 in 2013** is forecast to amount to approx. USD 2.8 bio. in 2017, given constant prices.

- For the purpose of the calculations, the proportion of **pharma grade lactose** is assumed to account for **15 - 17%** of the global lactose market volume, a proportion assumed to remain constant in the 2017 forecast.

- **Permeate is forecast to experience a higher volume growth rate** towards 2017 than for lactose.
Price development
- volatility characterises whey and lactose prices

- **Whey prices went up in 2013**, whereas lactose prices continued to soften. Prices are still at a profitable level for the whey processing industry.

- **Whey and lactose prices are fairly volatile** and they strongly reflect the global supply and demand situation for milk and dairy commodities in general.

- **More refined ingredients are less affected by price volatility than commodities.** This is exemplified by the WPC80 price, currently driven by demand exceeding supply.
Whey demineralization

TECHNOLOGIES AND PRODUCTS
Whey demineralization

Nanofiltration  Electrodialysis  Ion-exchange
## WHEY DEMINERALIZATION PROCESSES (Pros & Cons)

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
<th>INCONVENIENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NANOFILTRATION (D25-D35)</strong></td>
<td></td>
</tr>
<tr>
<td>+ Most effective demineralization process, only consuming electricity, NF membranes replacement, and small quantities of CIP water and chemicals</td>
<td>– Mostly a monovalent demineralization process, i.e. increase the concentration of bivalents</td>
</tr>
<tr>
<td>+ 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.</td>
<td></td>
</tr>
<tr>
<td>+ Loss of whey proteins into NF permeate is nearly zero</td>
<td></td>
</tr>
<tr>
<td>+ Loss of lactose into NF permeate limited to about 1%</td>
<td></td>
</tr>
<tr>
<td><strong>ELECTRODIALYSIS (D50-D90)</strong></td>
<td></td>
</tr>
<tr>
<td>+ Very flexible. Demin rate controlled by conductivity.</td>
<td>– Brine stream saturated by minerals</td>
</tr>
<tr>
<td>+ Easily operated and fully automated</td>
<td>– Very limited possibility of mineral profile adjustment</td>
</tr>
<tr>
<td>+ Loss of whey proteins into brine is in the range 1-2%</td>
<td></td>
</tr>
<tr>
<td>+ Loss of lactose into brine about 2%</td>
<td></td>
</tr>
<tr>
<td><strong>ION EXCHANGE RESIN (D90 high grade)</strong></td>
<td></td>
</tr>
<tr>
<td>+ Mainly used for D90 production (removal of all ions)</td>
<td>– Higher volume of effluents</td>
</tr>
<tr>
<td>+ Mostly is used as a polisher after NF/RO/ED</td>
<td>– Resins regeneration consumes Acid &amp; Base chemicals</td>
</tr>
<tr>
<td>+ Loss of whey proteins vary around 5%</td>
<td></td>
</tr>
<tr>
<td>+ Loss of lactose limited to about 0,5-1%</td>
<td></td>
</tr>
<tr>
<td>+ Simple batch operation, fully automatic</td>
<td></td>
</tr>
</tbody>
</table>
## Typical specifications of demineralized whey

<table>
<thead>
<tr>
<th></th>
<th>Sweet whey</th>
<th>D25</th>
<th>D50</th>
<th>D70</th>
<th>D90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demin technology</td>
<td>-</td>
<td>NF</td>
<td>ED</td>
<td>ED</td>
<td>ED, IEX</td>
</tr>
<tr>
<td><strong>Proteins</strong></td>
<td>11.5% min</td>
<td>11% min</td>
<td>11% min</td>
<td>11% min</td>
<td>11% min</td>
</tr>
<tr>
<td><strong>Lactose</strong></td>
<td>72% min</td>
<td>75% min</td>
<td>77% min</td>
<td>79% min</td>
<td>81% min</td>
</tr>
<tr>
<td><strong>Fat</strong></td>
<td>1.5% max</td>
<td>1% max</td>
<td>1% max</td>
<td>1% max</td>
<td>1% max</td>
</tr>
<tr>
<td><strong>Ash</strong></td>
<td>8% max</td>
<td>6% max</td>
<td>4% max</td>
<td>2.5% max</td>
<td>1% max</td>
</tr>
<tr>
<td>Na mg/100g</td>
<td>700</td>
<td>540</td>
<td>380</td>
<td>290</td>
<td>70</td>
</tr>
<tr>
<td>K mg/100g</td>
<td>2500</td>
<td>1730</td>
<td>960</td>
<td>650</td>
<td>250</td>
</tr>
<tr>
<td>Ca mg/100g</td>
<td>500</td>
<td>400</td>
<td>300</td>
<td>250</td>
<td>40</td>
</tr>
<tr>
<td>Mg mg/100g</td>
<td>100</td>
<td>89</td>
<td>78</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>P mg/100g</td>
<td>600</td>
<td>477</td>
<td>354</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>Cl mg/100g</td>
<td>1700</td>
<td>955</td>
<td>210</td>
<td>130</td>
<td>15</td>
</tr>
<tr>
<td><strong>Moisture</strong></td>
<td>4% max</td>
<td>4% max</td>
<td>4% max</td>
<td>3% max</td>
<td>3% max</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>6 min</td>
<td>6.2 min</td>
<td>6.3 min</td>
<td>6.3 min</td>
<td>6.3 min</td>
</tr>
</tbody>
</table>

Besides normal food grade specifications, in infant formula instead of reducing 90% of the minerals the absolute mineral level needs to be below 1% in the final powder.
Application of demin whey products

- Demineralized Whey and Whey Powder
- Demineralized delactosed whey
- Demineralized permeate powder (lactose concentrate)
- Demineralized Whey Protein Concentrate (DWP-28)

Demineralized whey is used as an alternative to sweet whey, where lower mineral and higher lactose contents are required. The major end use sector for demineralized whey powder (DWP90), is the infant formula industry.

Products like D70-30 are alternative to food grade lactose, when moderate protein content provides additional nutritional or functional advantages. Other areas of application are in confectionery and a wide range of dairy products like:

- Beverages on whey basis
- Ice creams, chocolate
- Bakery
- Feed (piglet, calf)
Three different approaches are used in the infant formula industry:

1. demin whey 90 (+ a bit of lactose)
2. WPC 35 (+ lactose)
3. WPC 80 (+ a lot of lactose)

Since the infant formula also needs to contain a large percentage of lactose, the D90 approach is most straightforward (by only removing the minerals). However, approximately 40% of existing formulas do also use the WPC 35 or the WPC 80 route.
Whey demineralization

**ENHANCED ELECTRODIALYSIS BY MEGA**
Main historical process developers in whey demineralization technology

- **Applexion (now Novasep, France)**
  - Ion-exchange since 1970’s, NF/RO + ion-exchange since 2000’s
- **Filtration Engineering (now Tetra Pak, USA)**
  - NF Desal 5 since 1990’s
- **Ionics (now GE Water, USA)**
  - Continuous ED for production of D50/D70 since 1970’s
  - Continuous ED for production of D90 since 2014
- **Eurodia, France**
  - Continuous/Batch ED for production of D50/70/90 since 1980’s
  - Ion-exchange/NF/RO/ED combined process (Saphir patent)
- **MEGA, Czech Republic (since 2006 on whey demin market)**
  - Batch ED production of D50-90 since 2006’s, NF/RO+ED combined process
  - MEGA has industrial experience with conversion of acid whey to food grade product by ED only
  - More than 50 installations of ED process for whey processing since 2006
- **Novasep & MEGA (collaboration since 2010)**
  - Combine the best of NF-ED-IEX optimized setup for high grade D90
Electrodialysis can proportionally decrease (but not completely remove) mineral content therefore **initial mineral composition of the whey is very important.**

**ED MEGA is suitable for common D90 with total ash content less than 1% only.** Some customers also require mineral profile -> **D90 high grade (combined process)**

### Composition of DEMI 90 products

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard DEMI 90 ED-IEX</th>
<th>Typical DEMI 90 (EDW) ED competition</th>
<th>Typical DEMI 90 ED MEGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>Max. 3.0% by oven</td>
<td>typical 2,7% max. 3%</td>
<td>Max. 3%</td>
</tr>
<tr>
<td></td>
<td>Max. 4.5% by karl fisher</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>Min. 12%</td>
<td>min. 12% typical 13%</td>
<td>12% - 13%</td>
</tr>
<tr>
<td>pH at 10% solution.</td>
<td>6.3 - 7.1</td>
<td>min. 6.5</td>
<td>6.0 - 7.0</td>
</tr>
<tr>
<td>Heat stability (no flocculation)</td>
<td>15%, 10 min. for 100°C</td>
<td></td>
<td>12%, 90°C, 6 min.</td>
</tr>
<tr>
<td>Chloride</td>
<td>Max 250 mg/100g</td>
<td>20 mg/100g</td>
<td>20 mg/100g</td>
</tr>
<tr>
<td>Sodium</td>
<td>Max 150 mg/100g</td>
<td>20 mg/100g</td>
<td>70 mg/100g</td>
</tr>
<tr>
<td>Potassium</td>
<td>Max 420 mg/100g</td>
<td>400 mg/100g</td>
<td>120 mg/100g</td>
</tr>
<tr>
<td>Calcium</td>
<td>Max 230 mg/100g</td>
<td>150 mg/100g</td>
<td>120 mg/100g</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>Max 150 mg/100g</td>
<td>160 mg/100g</td>
<td>140 mg/100g</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Max 50 mg/100g</td>
<td>70 mg/100g</td>
<td>30 mg/100g</td>
</tr>
<tr>
<td>Fat</td>
<td>Max 1 g/100g</td>
<td>typical 1 % max. 1,5%</td>
<td>0,5 - 1,5%</td>
</tr>
<tr>
<td>Total Ash</td>
<td>Max 1 g/100g</td>
<td><strong>typical 1,3 % max. 1,5%</strong></td>
<td><strong>Max. 1,0%</strong></td>
</tr>
</tbody>
</table>
Electrodialysis (ED) is used to transport salt ions from feed solution through ion-exchange membranes to concentrate (brine) under the influence of an applied electric potential (DC current), i.e. ED removes ionized particles and leaves other constituents behind.

**Key aspects for efficient ED process:**
1. Membrane properties (ions transport, surface, resistance, chemical stability)
2. Current efficiency, applied amperage
3. Temperature an pH (product & brine)
4. Time (product hold-up in system)
5. CIP efficiency
6. Stack design: plate-and-frame ion exchanger (horizontal, vertical)
Custom RALEX® ion-exchange membranes

Heterogeneous membranes have several benefits in whey demineralization compared with homogeneous membranes:

- Open structure with large channels for small monovalent and large divalent ions => Far better and more uniform ions transfer rates compared to homogeneous membranes
- Excellent mechanical properties. In case of drying up, possibility to swell again.
- High chemical resistance (pH 1-14)
- Long life-time
Basic process flow diagram & requirements

**Feed Requirements:**
- Separation + clarification
- Pasteurization
- Fat = max. 0.22%
- Undissolved solids = max. 0.1%
- Total solids = max. 22%
- Particle size = max. 10 μm
- Temperature = 10-15°C

**Process Utilities:**
- Electrical energy
- Water
- HNO₃ (HCl)
- NaOH
- NaNO₃ (Na₂SO₄)
- pH correction:
  - NaOH, KOH, NH₄OH

**Process Water Quality:**
- RO, or filtered potable water
- Conductivity < 250 μS/cm
- Ca < 20 mg/l
- Fe < 0.3 mg/l
- Mn < 0.02 mg/l
- SO₄²⁻ < 50 mg/l
- Silica < 20 mg/l

**Product Quality:**
- Ash < 1%
- Mineral composition depends on initial levels.
- Heat stability OK

**Working Conditions:**
- Low temperature (10-15°C)
- Natural pH
- Batch time max. 4 hours
- ED reversal
# What to consider? Important aspects for design.

<table>
<thead>
<tr>
<th>Item</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed quality</td>
<td>Different feed needs different approach (sweet, acid, casein, delactosed whey, etc.). Off-spec feed will cause operational problems.</td>
</tr>
<tr>
<td>Process water quality</td>
<td>For brine make-up, CIP and rinse. Improper water quality can cause higher water consumption for brine dilution or membrane fouling/scaling/poisoning.</td>
</tr>
<tr>
<td>Membrane fouling</td>
<td>Clogging of membrane surface by large molecules (mainly protein &amp; fat) cause decrease of ions transportation through membrane.</td>
</tr>
<tr>
<td>Membrane scaling</td>
<td>Insoluble precipitates on (or in) membrane. Mainly calcium phosphate $\text{Ca}_3(\text{PO}_4)_2$ due to removal of $\text{PO}_4^{3-}$ and $\text{Ca}^{2+}$ from whey. Precise brine stream adjustment (pH, temperature) is very important!!</td>
</tr>
<tr>
<td>Membrane poisoning</td>
<td>Impact of aggressive chemicals on ion-exchange groups in membrane structure like oxidants (hydrogen peroxide, etc.). Membrane is irreversibly damaged.</td>
</tr>
</tbody>
</table>
| Temperature                 | Higher temperature $\Rightarrow$ higher conductivity, better ED performance, higher microbiological growth  
Low temperature $\Rightarrow$ lower ED performance, prevention of microbiological growth  
Fast temperature changes can cause ED stack leakages due to thermal extensibility of membrane and spacers.                                      |
| Cleaning in place (CIP)     | Effective removal of minerals and organic compounds from the system. CIP conditions depends on membrane chemical and thermal stability.                                                                     |
| Effluent requirements       | Waste water enriched by minerals from whey, chemicals from process (adjustment of pH) and CIP. Effluent treatment is designed in accordance to local conditions (WWTP, output limits, etc.) |
From lab/pilot trials to industrial plant
Wide equipment portfolio

- To achieve economical processing, we are offering a wide range of products and capacities.
- From the smallest units (e.g. for acid whey conversion) to nation-wide whey processing.
- Equipment can be customized in accordance to customer’s standards (SCADA, sensors, pumps, valves, etc.)
Full automation and process control

Desalination batch D90

Offered control systems:
- Siemens/SINAMICS or IGSS
- Emerson PM/DeltaV
- Schneider/MODICON
- Rockwell/ALLEN-BRADLEY
Typical costs of enhanced electrodialysis for D90 production from NF sweet whey

- Electrical energy (process driving force)
- Water consumption (brine make-up, CIP, chilled)
- Chemical consumption (acid and caustic for process and CIP)
- Spare parts consumption (membranes, spacers, electrodes)

Average ED operating cost is **50 – 60 EUR/ton**.
Market price of WP varies **600 – 1 000 EUR/ton**.
Market price of D90 varies **1 600 – 2 300 EUR/ton**.
Extended warranty and care

- **Mechanical warranty** 24 months for all the equipment, machinery, instrumentation and devices, assembly and installation.
- **Process warranty** about capacity, consumptions, heat stability, microbiological safety and demineralization performance.
- **Life-time of main consumables** (maximum consumption per year*):
  - ED membranes: 4 years (annual replacement rate 25%)
  - Spacers: 10 years (annual replacement rate 10%)
  - Electrodes: 1,5 year (annual replacement rate 67%)

*Figures are valid for sweet whey demineralization (D70-D90) and 330 days/year
Our global market presence

- More than 50 projects worldwide
- Installed capacity ~ 250,000 tons DM/year
- 12 projects on acid whey demineralization
Main features of MEGA “enhanced electrodialysis”

✓ Process flexibility. Different types of whey (sweet, lactic acid, casein and salty) as well as different demineralization levels (D50 - D90) by one equipment.
✓ Low temperature & Natural pH of raw feed. Processing temperature 10 (8) - 15 °C to avoid microbiological growth in whey product. No acidification - no risk of precipitation -> preservation of protein value and process stability.
✓ Compliance with heat stability tests.
✓ Lower production costs in comparison to other suppliers. Optimized energy consumption for the process as well as longer lifetime of main consumables providing competitive advantage on D90 market.
✓ Advantage of ED with reversal but no mixing product/brine during production. Switch of polarity and flow circuits (self mechanical cleaning of membrane surface) is carry out after each batch in accordance to special reversal procedure.
✓ Easy operation and handling: Full automation. Mechanical cleaning of membrane surface (stack opening) is not needed and chemical cleaning is achieved using with just HNO₃ and NaOH; no enzymes, no steam are required.
✓ Equipment sanitary design: The whole equipment is microbiologically safe thanks to sanitary design, food grade membranes and low process temperature.
✓ Extended warranty and care: We guarantee quality of manufacturing as well as the capacity, demineralization performance, product heat stability & microbiological safety and operating expense.
✓ Certified quality: ISO certificates, EU hygiene, CE and GOST R, Kosher and Halal.
Competence in supply of electrodialysis with flexibility and high quality, worldwide.
Thank you for your attention!

We are looking forward to meeting you at our stand D 91 (hall 9.1)

Visit the MEGA stand at Anuga FoodTec in Cologne.

March 24 - 27, Hall 9.1, stand D 91