Current and Future Processing of Whey Ingredients

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Center for Dairy Research “Solution Based Research Backed by Experience, Passion and Tradition”
Why Process the Whey?

Distribution of Milk Components Between Cheese and Whey

Water
Total solids
Casein
Whey protein
Fat
Lactose
Calcium

50% of the solids are in the whey
Options for the Use of Whey

- Individual proteins
  - Lactoferrin
  - GMP
- Whey protein isolates
- Whey protein concentrates
  - WPC 80
  - WPC 34
- Whole whey

Increasing Value and Complexity to Produce

Feed
Land application
How is Whey Used?

Self Reported Values for Whey Use in 2012*

- Human Food: 65%
- Animal Feed: 35%

Amount of whey that is not used for either feed or food is not well documented.

*ADPI 2012 Dairy Ingredient Utilization
Distribution of Whey Products Used for Human Food in 2012
WHEY COMPONENTS
Components of Whey

- **Proteins**
  - Whey proteins
    - $\alpha$-lactalbumin
    - $\beta$-lactoglobulin
  - “Minor proteins”
    - lactoferrin
    - lactoperoxidase

- **Fat**
  - Phospholipids

- **Minerals (ash)**
  - Calcium phosphate

- **Lactic acid**

- **Lactose**

- **Non protein nitrogen**
# Concentration of Whey Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration (%)</th>
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<td>Water</td>
<td>93.5</td>
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<tr>
<td>Fat</td>
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<td>Phospholipid</td>
<td>0.12</td>
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<td>Whey protein</td>
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<td>β-Lactoglobulin</td>
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<td>Lactose</td>
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<td>Minerals</td>
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<td>Calcium</td>
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<tr>
<td>Phosphorous</td>
<td>0.04</td>
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<td>Potassium</td>
<td>0.15</td>
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Types of Whey and Handling Considerations

- **Sweet**
  - Easiest whey to handle

- **Acid**
  - Calcium and lactic acid are a problem
  - Can be made into WPCs but requires more effort

- **Fermented**
  - Lactic acid issues
  - Accelerated Maillard browning potential
  - WPC and/or permeate drying issues
Types of Whey and Handling Considerations (continued)

- **Organic**
  - Depends on composition
  - Potentially higher value product
  - Must be segregated/handled separately

- **Sheep, goat, mixed milks**
  - Potentially higher value
  - Smaller amounts increase processing costs

- **Kosher**
  - Majority of whey processing plants are kosher
  - Non kosher whey not accepted at kosher plants
## Acid and Greek Yogurt Whey

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<th>Component</th>
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<th>Acid</th>
<th>Greek</th>
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<tr>
<td>Total solids (%)</td>
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<td>Protein (%)</td>
<td>0.8</td>
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<td>0.3</td>
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<tr>
<td>Lactose (%)</td>
<td>4.9</td>
<td>4.4</td>
<td>4.2</td>
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<tr>
<td>Minerals (%)</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
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<td>Calcium (mg/100g)</td>
<td>45</td>
<td>103</td>
<td>123</td>
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<tr>
<td>pH</td>
<td>~ 6.0</td>
<td>&lt; 5.5</td>
<td>4.2</td>
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</table>

The problem: Acid whey is tough to process because of the mineral and acid content but has protein for value. Greek yogurt whey has even more acid and minerals and virtually no protein.
THE STARTING POINT
Basics of Whey Processing

- Fines removal
- Whey cream removal
- Pasteurization
- Bleaching (optional)
- Storage
Fines Removal

- Undesired in whey
  - Fines are insoluble
  - Flavor issues
- Presence adversely affects whey cream removal
  - Remove before whey cream
- Ripped bags and undersized equipment are sources of fines in whey
- Limit – less than 100 ppm
Whey Cream Removal

- Undesired flavor and functionality in whey products
- Need whey with:
  - Less than 0.08% fat to make WPC34
  - Less than 0.04% fat to make WPC80
- Typical target
  - Approximately 0.06% fat
Pasteurization

- Eliminate pathogens
- Reduce activity of starter culture
- Inactivate rennet
- Time/temperature
  - <16.5% total solids – regular pasteurization times/temperatures
  - >16.5% total solids – modified time/temp
Bleaching

Most customers want white whey
Bleaching to remove color
- Hydrogen peroxide
- Benzoyl peroxide

Issues
- Incomplete color removal
- Possible off flavor development
- Presence of benzoic acid and foreign markets
Storage of Whey

- Regulations dictate time/temp
- Food safety issue
  - Growth of pathogens
  - Production of heat stable toxin by Staph
- Product quality issue
  - Acid production and sticky whey
Cheese Culture Growth in Whey

No growth in raw or pasteurized whey at 37 or 60 F
Cheese Culture Growth in Whey
(continued)
End Results of Drying Problem
Whey

- Increased rate of Maillard browning
- Scorch
- Clumping
- Material sticking to dryer walls
- Blocked valve
CATEGORIES OF WHEY PRODUCTS
Whey

Concentrate

Fractionate

Convert

Organic matter
  
  Fermentation
    
    Single cell protein

Chemicals
  
  Chemical conversion/Fermentation
    
    Ethanol Methanol Lactitol

Fuels
  
  Chemical conversion/Fermentation
    
    Methane Ethanol
Converting Example

Galacto-oliosaccharides

- Oliosaccharide – carbohydrate composed of 2 to 10 monomer sugar units linked together
- Produced from lactose
  - Japan (mid 1980’s) and Europe (1995)
- Functional food
  - Prebiotic
  - Added to infant formula
  - Many health claims made but lack well-conducted clinical trials
An Example of a Galacto-oliosaccharide

[lactose]

4'-galactosyl lactose
What are the Issues with Conversions?

- Fermentations are never easy
- Low rates of conversion
- Typically must still purify
- What is the end product? Who is it for?
- What is the market for the ingredient?
- Alcohol is main conversion but hard to compete against corn
Concentrating

- No additional value to components
- Cost savings for shipping through water removal

Examples
- Whole whey powder
- RO/Evaporated whey
Whole Whey Powder

- All components of whey except water
- Equipment required
  - Evaporator
  - Crystallizer/cooling
  - Spray dryer
  - Packaging equipment
- Byproducts
  - COW water
Value added products produced by fractionating

Method used to fractionate helps determine purity and cost of ingredient

- Membranes versus chromatography
- WPC versus purified lactoferrin
FRACTIONATED WHEY INGREDIENTS
Whey Products

- Condensed/dried whey
  - sweet, acid
- Demineralized whey
  - 25, 50 and 90%
- Reduced lactose whey
  (mineral-concentrated)
- Whey protein concentrate
  - 34, 50, 60, 75 and 80%
- Whey protein isolate
- Lactose hydrolyze whey
- Protein hydrolyzed whey

- Lactose
  - industrial, food and pharmaceutical
- Lactose derivatives
  - lactitol, lactulose and galacto-oligosaccharides
- Individual proteins
  - lactoferrin, lactoperoxidase and glycomacropeptide
- Dairy minerals
- Permeate
Dairy Ingredients Made From Whey

Percentage of Total Solids

- Sweet whey
- Acid whey
- 25% Demin
- 50% Demin
- 90% Demin
- Reduced lact
- Mineral conc
- WPC-34
- WPC-80
- WPI
- Permeate
- a-lactalbumin
- Lactoferrin
- GMP
- Dairy minerals
- Lactose

Legend:
- Fat
- Ash
- Lactose
- Protein
Basic Assumptions

Assumptions for all whey for further processing:
- Cheese fines removed
- Whey cream removed
- Whey has been pasteurized
- Final product is to be dried
Membrane Fractionation for WPCs

- Spiral-wound
- Hollow fiber
- Tubular
- Ceramic
- Plate and frame
Whey Protein Concentrates and Permeate

Pasteurized Fluid Whey → Ultrafiltration → Whey Protein Concentrate → Concentration/Spray Drying → 34 to 50 WPC

Pasteurized Fluid Whey → Ultrafiltration → Diafiltration → Concentration/Spray Drying → 50 to 80 WPC

Permeate
The Problem with Permeate

Courtesy of Todd Hutson, Filtration Engineering Co, Inc
The Problem with Permeate (continued)

- By product of WPC production
- Contains minerals and lactose
- Large volume
  - Original whey minus WPC volume (if no DF used)
- Low total solids (<5%)
- Costly to convert to dry product
- Expensive to ship if not concentrated
- High BOD if goes to sewer
- Limited ability to land apply
Composition of Milk, Whey and Permeate

![Bar chart showing the composition of Milk, Whey, and Permeate with different percentages of fat, ash, lactose, and protein.](chart.png)
Permeate Options

- Dry
- Lactose (~60% yield) with DLP byproduct
  - DLP generally land applied, animal feed
- Fuel
- Feed
- Digester
- Conversion
  - Oligosaccharides, hydrolysis
Permeate (continued)

- Equipment required to process permeate
  - Evaporator
  - Crystallizer
- Expensive to process given value of final product
Yield for Products from Milk

![Bar chart showing yield based on total solids for different products from milk. The chart compares milk, cheese, whey, WPC34, WPC80, and WPI in terms of ingredient and byproduct yield.](chart.png)
Additional Whey Ingredient Possibilities

Either not for beginners or small market products or both

- Reduced lactose whey
- Lactose hydrolyzed whey
- Protein hydrolyzed whey
- Demineralized whey
- Individual proteins
- Dairy minerals
- Lactose
HIGH PURITY PROTEINS
Individual Whey Proteins

- Lactoferrin  
  – >90% purity
- Lactoperoxidase  
  – 92% protein
- Glycomacropeptide  
  – >90% purity
- Lysozyme  
  – Isolated with lactoferrin and lactoperoxidase
Chromatography Basics

- Resins
  - Beads or granules of organic or sometimes inorganic materials which have the ability to absorb molecules under certain conditions
- Column containing separating resin beads
- Add liquid containing two or more compounds to be separated
- One compound is attracted and flows slower than other compound thereby causing gradual separation
Basic Steps in Ion Exchange Chromatography
Thoughts on Future for High Purity Proteins

- Chromatography only large scale method for isolating individual proteins at this time.
- Aside from one company, no one is rushing to adopt this process for feed streams of >1 million pounds per day.
Thoughts on Future for High Purity Proteins (continued)

- Use of membranes in this area would require development of membranes with specific charges (similar to charged resin).
- Probably would need some adjustment to processing stream (pH, ionic strength, etc.) in conjunction with special membranes.
- Extremely difficult to achieve this goal.
Range of Membrane Separations in the Dairy Industry

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Enriched Protein Fractions

- Specific proteins or groups of proteins in higher concentrations than typically present
  - Not 100% pure

- Membrane technology used
  - Polymeric MF membranes
  - Hot or cold
  - Raw, pasteurized, whole, skim, whey, etc.
What is the Future for Dairy Ingredients?
Possibilities - General

- Concentrates with different levels of protein, fat, lactose and minerals and depleted or enriched in certain protein fractions
- Separation of the milk ahead of cheese manufacture to produce native whey protein concentrates/isolates, reduced $\beta$-casein in milk/ $\beta$-casein enriched whey fraction
- WPC80 with clarity and functionality of WPI
- Control of Maillard browning during storage
An Example: Beta-Casein

- Most surface active of all the milk proteins
  - Superior foaming/emulsification
- Possible replacement or substitute for imported sodium caseinate
  - $\beta$-casein is the key ingredient in sodium caseinate
- Source of numerous bioactive peptides
- Fortification of infant formula
  - Closer to human milk ratios of caseins
MF for $\beta$ -casein Reduction in Cheesemilk

- Implicated in melt properties and delayed flavor development in cheese

Goal:
- Retentate is partially depleted of $\beta$ –casein
- $\beta$ -casein with whey proteins in permeate fraction
Beta-Casein Purification Process: Maintains beta-casein with high solubility and functionality

Publication Classification

Int. Cl. A23C 19/00 (2006.01)
U.S. Cl. .................................................. 426/582

ABSTRACT

A method is provided for obtaining β-casein from skim milk. Purification of β-casein from milk is achieved through a process of microfiltration using cross-flow polymeric microfiltration membranes. Cooling of the milk prior to microfiltration results in improved separation of β-casein from the other milk serum proteins. Further filtration and demineralization of the microfiltered permeate results in enrichment of the fraction containing soluble β-casein. An integrated scheme that allows a dairy plant to continuously separate and purify β-casein is provided. Also provided is a method for obtaining cheese with improved meltability and reduced bitterness.
# Comparison of Foaming Performance

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<thead>
<tr>
<th>Sample</th>
<th>Overrun (%)</th>
<th>Stability (minutes)</th>
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<tbody>
<tr>
<td>5% WPC</td>
<td>&lt;800</td>
<td>&lt; 8</td>
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<tr>
<td>1% Beta-casein</td>
<td>1380</td>
<td>32</td>
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</tbody>
</table>
Options for Whey Proteins and \( \beta \)-casein

- Skim
- Whole milk

\( \rightarrow \)

MF

- Cold
  - Retentate (concentrated casein - \( \beta \)-casein depleted)
  - Permeate (\( \beta \)-casein/whey proteins)
  - UF
    - Retentate (\( \beta \)-casein)
    - Permeate (whey proteins)

- Warm
  - Retentate (concentrated casein)
  - Permeate (whey proteins)

Multiple value added streams possible
Chitosan and Color/Fat Removal

- Chitosan is added to whey and binds to annatto
- A chitosan/fat/color complex is flocculated and removed by microfiltration

Possibilities - Membranes

- Finer fractionation
  - $\alpha$ and $\beta$ enhanced fractions

- Membranes that fill the gap
  - 700 dalton NF (loose NF/tight UF)
  - 50 to 100 kdalton UF

- NF membranes are the new opportunity
Possibilities - Europe

- More demineralized whey (NF)
  - Due to high volume of acid whey from quark
- Quotas removed in Europe next year
  - Extra milk supply
  - Will add cows despite high price of land
  - MF protein production
  - Ireland – not making cheese but powder instead
  - Example: Glanbia and Waterford
Drivers

Europe
- More milk with quotas removed
- Less regulatory issues regarding MF products

Pepsi, Coke, etc.
- Want diversification into protein beverages
- Beverages big driver but will the new products be seen as dairy beverages?
Drivers (continued)

China
- Bigger consumer than people think
- Internal quality issues
- Will not be exporting
- Not a consumer of fluid (drinking) milk
- Infant formula
- #1 dessert is ice cream
Hurdles to Technology

- Regulatory
  - FDA stance on MF vs UF for cheesemilk
- Applications for end products
- Low concentrations of some components and cost to produce
- What to do with the byproducts?
Because the market for a new ingredient does not exist yet, marketing cannot supply demand numbers and without demand numbers project to produce the new ingredient cannot get approval but if there is no ingredient then how does the demand develop? – Catch 22
QUESTIONS?
Thank You

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