Flavor Considerations in Dried Dairy Ingredients

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What consumers want

- **Moving and changing** target
- Lots of different targets
- Not one magic bullet
- Product and consumer research combined with innovation used to meet consumer and customer targets
What are the targets?

• Functionality and nutrition are targets and so is **flavor**

• For ingredient applications, **no flavor carry through** is the desired target for dairy proteins
Why IS flavor of dairy ingredients important?

• Off-flavors are present in whey proteins (Carunchia Whetstine et al., 2005; Russell et al., 2006; Drake, 2006; Wright et al., 2006; 2008)
  – All ingredients DO NOT taste the same

• Dried ingredient flavor can carry through into finished products (Russell et al., 2006, Drake, 2006; Drake et al., 2008; Childs et al., 2007; Wright et al., 2008)
Sensory profiles of WPC80 (Trained panel)

Aroma intensity:
- fatty
- raisin
- cardboard

Sensory profiles:
- PC1 38%
- PC2 22%

Attributes:
- brothy
- soapy
- cereal
- Swt aromatic
- Sour aromatic
Consumer Acceptability
Liking of peach protein beverages

N=65 consumers

Whey proteins with least Flavor make preferred beverages
What do Consumers want?

Drivers of Liking for Protein Beverages

Conjoint survey
- Decomposes product into attributes to determine consumer value
- Respondents indicate preference between hypothetical products

Kano analysis
- Classifies consumer needs
- Consumer needs based on how they affect satisfaction

Cluster analysis
- Differentiates groups of consumers who prefer different attributes
Protein beverages

• What do consumers want?
• Conjoint survey (440 consumers)
  – Label claim
  – Protein type
  – Protein amount
  – Sweetener
  – Metabolic benefits
• Kano analysis to uncover drivers
Specific protein beverage attributes – ideal product

- Whey protein (followed by milk protein)
- $\geq 10$ g per serving (15 or 20 g preferred)
- Naturally sweetened
- Keeps you full
- Great taste

Kano analysis: Great taste and satiety are drivers
Key consumer attributes for protein beverages

![Bar chart showing importance scores for different attributes across clusters and overall.]

**Overall**:
- **Protein type**: Importance scores are high across all clusters.
- **Label claim**: Moderate importance scores across clusters.
- **Protein amt**: High importance scores, especially in cluster 2.
- **All natural**: High importance scores in cluster 3.
- **Great taste expectation for all consumers**: High importance scores for all clusters.

**Clusters**:
- **Cluster 1 (N=90)**: Similar importance scores for protein type and label claim.
- **Cluster 2 (N=160)**: Highest importance scores for protein amt.
- **Cluster 3 (N=189)**: Highest importance scores for all natural.

**Importance scores**:
- **N=440**
- **Protein type**, **And label claim**, **Protein amt**, **All natural**, **Great taste expectation for all consumers**

Legend:
- **label claim**
- **protein**
- **amt prot**
- **sweetener**
- **benefits**
Protein Beverage Kano Frequencies

**Attractive**: All natural, 20 g protein, vitamins and minerals, calcium

**Driver**: Tastes good

**Must Have**: Tastes good, satiety, 15 g protein

**Reverse**: artificial sweetener
## Cluster Drivers

<table>
<thead>
<tr>
<th>Cluster 1 (n=86)</th>
<th>Kano</th>
<th>Conjoint</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Great taste</td>
<td>-Protein type</td>
<td>Overall protein beverage consumers</td>
<td></td>
</tr>
<tr>
<td>-Keeps you full</td>
<td>-Amount of protein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-All natural</td>
<td>-Sweetener</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Vitamins and minerals</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cluster 2 (n=184)</th>
<th>Kano</th>
<th>Conjoint</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Great taste</td>
<td>-Sweetener</td>
<td>Natural and sweetener-aware consumers</td>
<td></td>
</tr>
<tr>
<td>-Keeps you full</td>
<td>-Protein type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Artificial sweetener: reverse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-All natural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Vitamins and minerals (plus calcium)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cluster 3 (n=162)</th>
<th>Kano</th>
<th>Conjoint</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Great taste</td>
<td>-Amount of protein</td>
<td>Protein content aware and lower sugar consumers</td>
<td></td>
</tr>
<tr>
<td>-Keeps you full</td>
<td>-Protein type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-15 &amp; 20 grams protein per serving</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-Reduced amounts of sugar</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Consumer acceptance of protein beverages

Beverage manufacture

Consumer testing with and without priming statements

Does priming have an effect on liking?
Liking of protein beverages
No information provided

N=150 consumers

10g/serving
Fresh vs stale

10 g vs 20 g/serving
Fresh

Flavor of the protein source and amount of protein impact consumer acceptance
Liking of protein beverages
Priming information provided

N=150 consumers

“Great taste!”
10g/serving
Fresh vs stale

“20 g prot/serving”
10 g vs 20 g/serving
Fresh

Protein label influences liking but NOT as much as actual flavor of the product
Bottom line

• **What are the targets?**
  – Microbial quality (shelf-life and safety)
  – Consistency (composition, functionality)
  – **Flavor**

• **Sensory** quality is a critical aspect of dried ingredient quality

• **Off flavors**: cardboard, fatty, cabbage in *whey proteins*, animal, tortilla, fatty, cabbage in *milk proteins*
Flavor sources in dried ingredients

• Lipid oxidation and sulfur degradation products are the primary sources of off flavors in WPC80 and WPI

• Maillard reactions play a role at higher storage temperature and or higher lactose concentrations

• Three flavor sources:
  – Cheesemake and starter (whey/permeate)
  – Manufacture/processing
  – End user processing
Dried Ingredient flavor

• Whey Ingredients
  – Impact of cheesemake
  – Impact of whey processing

• Permeate as an ingredient and salt substitute
Impact of cheesemake

*Sensory profiles of WPI*

- Sweet Aromatic
- Mozzarella
- Rennet casein
- White Cheddar
- Cottage cheese
- Astringency
- Potato Brothy
- Sour

Aroma Intensity
- Cabbage
- Fatty
- Cardboard
- HP bleached Cheddar

F1 (54.61 %)
F2 (40.44 %)
Influence of cheesemake

Cardboard Flavor vs. Total Aldehydes

- Cardboard
- Total Aldehydes (ppb)

<table>
<thead>
<tr>
<th>Whey Source</th>
<th>Cardboard Sensory Intensity</th>
<th>Total Aldehyde (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheddar</td>
<td>1.4</td>
<td>250</td>
</tr>
<tr>
<td>Mozzarella</td>
<td>1.2</td>
<td>150</td>
</tr>
<tr>
<td>Rennet</td>
<td>1.1</td>
<td>50</td>
</tr>
<tr>
<td>Cottage</td>
<td>1.4</td>
<td>250</td>
</tr>
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Whey Protein Processing

• Influence of processing -- several sources. A few include:
  – Membrane sanitation and cleaning
  – Fat separation
  – **Storage of fluid product**
  – **Bleaching**
  – Solids and pH at spray dry
  – Storage of dried product and instantization
Impact of **fluid storage** on final product flavor

- Longer storage \(\rightarrow\) increased lipid oxidation
- Mozzarella WPC80 and Cheddar WPI retentate
  - stored at 3 C and spray dried every 4 or 6 h through 48 h
- Same trends observed for both products
Impact of liquid retentate storage at 3 C on flavor of spray dried Cheddar WPI

Increase in storage time Increases stale/fatty And cabbage flavors
ROLE OF STORAGE
Impact of liquid retentate storage at 3°C on volatiles of spray dried Cheddar WPI

Lipid and protein oxidation
Increase with storage
Fluid storage

• Fluid product should be stored < 6 h
  – Lipid oxidation products and sensory off-flavors in WPC80 and WPI increased with 3C storage of retentate

• Current follow up: which is more critical, fluid whey or fluid retentate? How large is the impact of bleaching on storage?
Liquid Storage of Whey

• For liquid storage, which point is most critical?

• Bleached and unbleached liquid Cheddar whey manufactured and stored or ultrafiltered (UF) to 15% solids and stored 24 h at 4C

• Fluid wheys were then ultrafiltered to 15% solids and spray dried (WPC80)
Storage of Liquids

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Aroma Intensity</th>
<th>Sweet Aromatic</th>
<th>Cardboard</th>
<th>Cabbage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unbleached Control</td>
<td>2.5ab</td>
<td>1.9a</td>
<td>0.5d</td>
<td>ND</td>
</tr>
<tr>
<td>Unbleached Liquid Whey Stored</td>
<td>2.1b</td>
<td>1.0b</td>
<td>1.2c</td>
<td>ND</td>
</tr>
<tr>
<td>Unbleached Liquid Retentate</td>
<td>2.3ab</td>
<td>1.4b</td>
<td>0.7d</td>
<td>ND</td>
</tr>
<tr>
<td>Stored</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bleached Control</td>
<td>2.8a</td>
<td>ND</td>
<td>2.3b</td>
<td>1.1a</td>
</tr>
<tr>
<td>Bleached Liquid Whey Stored</td>
<td>2.8a</td>
<td>ND</td>
<td>2.2b</td>
<td>1.1a</td>
</tr>
<tr>
<td>Bleached Liquid Retentate</td>
<td>2.6a</td>
<td>ND</td>
<td>2.9a</td>
<td>1.1a</td>
</tr>
<tr>
<td>Stored</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- Storage of liquid whey decreased sweet aromatic and increased cardboard flavors compared to the control (p<0.05).
- Storage of liquid retentate was not different from the control in cardboard flavor (p>0.05).
• Liquid storage increases off-flavors in both WPC and SMP.

• If liquid storage is necessary:
  – Condensed milk should be concentrated by RO rather than E to reduce off-flavors
  – Unbleached fluid whey should be stored as retentate, bleached product should be stored as whey
Role of bleaching

• Annatto (norbixin) added to cheesemilk carries over into fluid whey, imparts undesirable color to spray dried product

• Only 10% of norbixin added to cheesemilk partitions into the whey stream (Smith et al., 2014)

• Norbixin plays no direct role in flavor of whey or whey protein (Campbell et al., 2010)

• Bleaching plays a LARGE role in off flavors of dried whey ingredients
Rehydrated WPC80 at 10% Solids

Anatto No Bleach

Anatto BPO

Anatto Hydrogen Peroxide
Bleaching agents

• Bleaching applied to fluid whey or retentate
• Two approved chemical agents in U.S.
  – Hydrogen peroxide (HP) (up to 500 ppm)
  – Benzoyl peroxide (BP) (regulated by GMP)
• Enzymatic bleaching
  – Lactoperoxidase
  – Commercial peroxidase (Maxibright™)
• These are all non-specific oxidation processes
Chemical and enzymatic bleaching

- Increases lipid oxidation
- Increases cardboard, fatty and cabbage flavors
- Effects are impacted by:
  - Bleach type
  - Bleach concentration
  - Bleach temperature
Percent residual norbixin in liquid whey bleached with benzoyl peroxide or hydrogen peroxide

Percent norbixin

BP more effective
Regardless of temperature
In fluid whey

BP 100
HP 250

0 10 20 30 40 50 60 70 80 90 100

4C 16 h
50C 1 h
Percent residual norbixin in **liquid retentate** bleached with benzoyl peroxide or hydrogen peroxide

Both HP and BP are effective in retentate.
Total aldehydes in liquid whey bleached with benzoyl peroxide or hydrogen peroxide

![Graph showing the total aldehydes in liquid whey bleached with benzoyl peroxide or hydrogen peroxide.](image)
Total aldehydes in **liquid retentate** bleached with benzoyl peroxide or hydrogen peroxide.

Off flavors follow Oxidation, higher With HP compared to BP.
Sensory attributes and selected lipid oxidation compounds in WPC80

Similar results with SWP, WPC34, SPC80, WPI
Other alternatives?

- Milk lactoperoxidase
- External peroxidase (Maxibright™)

Both are peroxidases that destroy norbixin in the presence of low concentrations of hydrogen peroxide.

- Potential for high and fast norbixin destruction under wide temperature and solids concentration range.
Lactoperoxidase bleaching in fluid Cheddar whey from pasteurized milk at 35°C

Fast and nearly Complete bleaching

*HP 20 ppm
Cardboard flavor intensities higher in bleached WPC80
But lower in EP bleached WPC80
Norbixin removal

• Norbixin in whey is likely present in micelles or associated with milkfat/MFGM
  – Norbixin in whey is reduced by shear and by temperature (hot hold)
  – Reduction is enhanced by presence of additional salt (suggests some type/level of protein interaction)
  – Can be reduced by pH adjustment to 4.2
  – No evidence (from fluorescent spectroscopy) that norbixin binds to alpha or beta lactoglobulin

• Microfiltration removes fat from whey and should also decrease norbixin
Norbixin destruction or removal in WPC80

Microfiltration of fluid whey
Comparable to hot HP bleach

- MF: 46a
- HP: 46a
- LP: 95 b
WPC80 with and without norbixin reduction

Con  MF  HP  LP
Flavor solutions?

• Careful selection of protein ingredients
  – Flavor and age
• Careful processing parameters
• Careful selection of flavoring systems and sweeteners
• Minimize heat treatment
Whey and milk permeates

• By-product of whey or milk protein concentrate/isolate manufacture
  – Delactose or reduced lactose permeate by-product of lactose crystallization
  – Low molecular weight compounds (minerals, NPN, lactose, acids) that are not retained by UF membrane
  – Primary use is animal feed
Is permeate a salt substitute?

• Previous work has demonstrated that it can be used as a milk solids replacement and in place of salt in variety of foods
  – Baked goods
  – Cream soups
  – Frozen dairy desserts

• No direct evidence that it is a salt replacer

since it contains Na
Sensory properties of permeates

- **Whey permeates**: sweet aromatics, sweet taste, low salty taste (Mozz and Cheddar sources)
  - $X = 2.2$
  - Range = 1.3 to 4.4 (0 to 15 scale)

- **Reduced lactose permeates**: savory aromatics, higher salty taste
  - $X = 9.3$
  - Range = 8.0 to 12.8 (0 to 15 scale)
  - **Higher concentrations** of organic acids and NPN than whey permeates
Sensory profiles of whey (w) and reduced lactose (dlc) permeates
Volatile compound profiles of whey and reduced lactose permeates

Reduced lactose permeates have higher concentrations of volatiles, concurrent with higher sensory aromatic and salty taste intensities.
Sources of salty taste?

- **Sodium**
  - Whey permeates: $x = 1\%$ dry wt, reduced lactose permeates: $x = 2.5\%$ dry wt

- Other components with significant correlations with salty taste:
  - $K$
  - Lactic acid
  - Citric acid
  - Orotic acid
  - NPN (urea)  
  
  *Mg, Ca, uric and hippuric acids and nucleotides were not correlated ($p>0.05$) with salty taste intensity*
Salty taste response curves: NaCl alone

Salty taste of whey and delac permeates are higher than concentration of NaCl.
Salty taste response curves:
NaCl, 0.05M/0.1M KCl and 5% lactose

* Addition of lactose suppresses salty taste

model permeates

WP DLC
Summary

• KCl plays a critical role in salty taste
• Model permeate (NaCl, KCl and 5% lactose) used to screen other components
  – Citric acid
  – Lactic acid
  – Orotic acid
  – Urea

These components are all higher (p<0.05) in reduced lactose permeates compared to whey permeates
Proof of concept

Salty taste intensity

2 whey permeates with low Salty taste intensity

whey permeate 1

whey permeate 2

as-is
2 whey permeates with low Salty taste intensity – plus added KCl, lactic and orotic acids at the levels found in high salty taste delac permeates.
Salty taste components

- NaCl
- KCl
- Lactic acid
- Orotic acid
- Citric acid or urea did not enhance salty taste
- Frankowski et al., 2014. J.Dairy Sci
Permeate Applications

• 1 g of salt is replaced by 10 g permeate powder or 3-4 g delactose permeate powder which results in an **80% decrease in Na**

• Cream of broccoli soups:
  – Control: 0.44% added NaCl
  – Permeate soups: no added NaCl
Trained panel profile of soups

- control milk permeate
- whey permeate
- delac permeate
- no salt

Tastes:
- salty taste
- sour taste
- umami taste
- sweet taste
- metallic
cardboard

Sweet and umami
Trained panel profile of soups

- control milk permeate
- whey permeate
- delac permeate
- no salt

Taste profile:
- salty taste
- sour taste
- umami taste
- sweet taste
- metallic
- cardboard

Sour and umami indication.
Trained panel profile of soups

Salty but metallic and cardboard
Permeates

- Different (whey) sources of permeate may provide further salty taste enhancement
- Mozzarella, Cheddar, Cottage cheese and rennet casein whey manufactured, followed by fat separation, pasteurization and UF
- Milk permeate also manufactured
- Permeates collected and spray dried
Sensory profiles of permeates

Biplot (axes F1 and F2: 83 %)

- Sweet Aromatic
- Cardboard
- Vitamin
- Potato
- Aroma Intensity
- Salty
- Umami
- Sour
- Caramel
- Cottage cheese
- Commercial Whey permeate
- Commercial Milk permeate
- Mozz
- Cheddar
- Milk
- F1 (64 %)
- F2 (18 %)
Salty taste of permeates

Also sour and umami
Highest in lactic acid
Trained panel profile of soups

- Cheddar
- Milk
- Mozzarella
- Cottage
- No salt
- Salt control

Also sour and umami

Salty taste
Consumer acceptance of soups

N=110

Liking

Cheddar
Milk
Mozzarella
Cottage
no salt
salt control

1
2
3
4
5
6
7
8
9
Summary

• Flavor of dried ingredients matters

• Every step from milk receipt to spray dried product to final application influences whey protein flavor contributions
  – Processing and storage play a critical role

• Careful selection of ingredients and optimization of processing parameters can be applied to *minimize* flavor contributions and *maximize* flavor quality
Acknowledgements
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