Formulating with proteins: Processing and flavor challenges

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May 4, 2016
Why IS flavor of protein ingredients important?

• Off-flavors are present in proteins (Carunchia Whetstine et al., 2005; Russell et al., 2006; Drake, 2006; Wright et al., 2006; 2008)
  • *All protein ingredients DO NOT taste the same*
Sensory profiles of WPI (Trained panel)

PC1 (53%)

PC2 (16%)

WPI11
WPI8
WPI10
WPI7
WPI5
WPI3
WPI4
WPI6
WPI2
WPI9
WPI1

astringent

cabbage

brothy

soapy

bitter

Sweet aromatic

cardboard

grassy
Sensory Profiles of MPC and MPI

- Aroma intensity
  - Sweet aromatic
  - Cooked/milky
  - Cereal
  - Sweet taste
  - Increasing protein content

- F1 (43%)

- F2 (17%)

- Sensory Profiles of MPC and MPI

- Increasing protein content
  - Sweet taste
  - Astringent
  - Potato/brothy
  - Animal
  - Tortilla
  - Cardboard
Comparing whey and soy proteins

PC1 (55%)
PC2 (14%)

SPI1, SPI2, SPI3, SPI4, SPC1, SPC2, SPC3, SPC4, WPI1, WPI2, WPI3, WPI4, WPI5, WPI6, WPI7, WPI8, WPC1, WPC2, WPC3, WPC4, WPC5, WPC6

Averaged sensory attributes
- Astringency
- Sweet aromatic
- Opacity
- Viscosity
- Color
- Chalky
- Cereal
- Metallic
- Brothy
- Soapy
- Fecal
- Yeasty
- Bitter
- Salty
- Animal

-6 -4 -2 0 2 4 6
Why IS flavor of protein ingredients important?

• Off-flavors are present in 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 protein 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)

PC1 38%

PC2 22%

Aroma intensity

fatty

raisin

brothy

cardboard

soapy

Swt aromatic

Sour aromatic

cereal
Consumer Acceptability
Liking of peach protein beverages

Whey proteins with least Flavor make preferred beverages

N=100 consumers
Why IS flavor of protein ingredients important?

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- >50% consumers today are looking to place more protein into their diet
Protein beverages

- What do consumers want?
- Conjoint survey (440 consumers)
  - Label claim
  - Protein type
  - Protein amount
  - Sweetener
  - Metabolic benefits
Specific protein beverage attributes – ideal product

- Whey protein (followed by milk protein)
- ≥15 g per serving (20 or 25 g preferred)
- Naturally sweetened
- Keeps you full
- Great taste
Key consumer attributes for protein beverages

Great taste expectation for all consumers

N = 440

Protein type
Protein amount
All natural

Importance scores

Overall
Cluster 1
Cluster 2
Cluster 3

N = 90
N = 160
N = 189

- Label claim
- Protein
- Protein amount
- All natural
- Sweetener
- Benefits
Tasting is believing

• Two sets of fruit flavored clear acidic beverages manufactured:
  • Set 1: 10 g protein per serving, 2 different protein sources (1 minimal flavor, 1 >18 mo old, stale)
  • Set 2: Same WPI (minimal flavor), 2 different protein amounts (10 g per serving, 20 g per serving)
• Protein beverage consumers (n=150) evaluated each pair with and without labeling in a crossover design
Liking of protein beverages
No information provided

N=150 consumers

10g/ serving
Fresh vs stale

10 g vs 20 g/ serving
Fresh

protein source
protein amount

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
Sensory profile of protein beverages

More protein means more protein-related flavors and sensory properties

- fruity
- cardboard
- soap
- viscosity

10 g/serving vs. 20 g/serving
Protein Sensory effects

• More whey protein: more desirable to consumers conceptually
• More whey protein: higher cardboard flavor
• More whey protein: higher viscosity
• More whey protein: higher astringency

• More protein: more protein-related problems
The challenges

• Ingredient flavor and color carry through into finished product - **flavor is a challenge**

• **Shelf stability** – flavor and functional challenges

• Different challenges exist with different protein ingredients and different applications
Flavor sources in dried dairy protein ingredients

- Lipid oxidation and sulfur degradation products are the primary sources of off flavors in whey and milk proteins
  - Not the same compounds and not the same flavors

- Maillard reactions play a role at higher storage temperature and or higher lactose concentrations
  - Maillard reactions play a larger role in milk protein flavor/functional degradation at room temperature storage

- Three flavor sources:
  - Cheesemake and starter (whey ingredients)
  - Manufacture/processing/storage
  - End user processing
Influence of cheesemaking

- Dried whey ingredient flavor starts with the cheese milk → fresh fluid whey
- Fluid whey already has lipid oxidation compounds
- Annatto plays no direct role
- Starter culture increases oxidation
- Mesophilic > thermophilic
- Differences among mesophilic starters
Influence of cheesemake on WPI

![Image showing a graph with Whey Source on the x-axis and Cardboard flavor intensity and Total Aldehydes (ppb) on the y-axis. The graph compares Bleached Cheddar, White Cheddar, Mozzarella, Rennet, and Cottage cheese.]
Influence of cheesemake: heat stability

- WPI was heated to 141°C for 6 sec in 4% and 10% protein (w/v) solutions at pH 7.
- All WPI gelled at 10% concentration except for cottage cheese WPI.
Influence of cheesemake: foam overrun

- Cottage WPI produced a foam with lower overrun (p<0.05).
- This could be due to heat induced denaturation during the cottage cheese cook procedure.
Influence of cheesemake: Foam Stability

- Cheddar WPI had decreased foam stability (p<0.05).
Influence of Whey Protein Processing

- Influence of processing -- several sources. A few include:
  - Fat separation
  - Storage of fluid product
  - Bleaching
  - Solids and pH at spray dry
  - Actual spray drying
  - Storage of dried product and instantization
  - Many of these also impact milk protein flavor
Impact of fluid storage on final product flavor

• Longer storage → increased lipid oxidation
• Mozzarella WPC80 and Cheddar WPI retentate - stored at 3 C and spray dried every 4 or 6 h through 48 h (Whitson et al., 2011)
• Same trends observed for both whey proteins and for milk proteins
• Fluid storage should be <6 h
Impact of liquid retentate storage at 3°C on flavor of spray-dried Cheddar WPI

Aroma intensity:
- cardboard
- cabbage
- fatty

Increase in storage time increases stale/fatty and cabbage flavors.

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

- 2-nonanone
- 2-butenal
- Diacetyl
- Dimethyl sulfide
- octanal
- DMTS
- nonanal
- hexanal
- Dimethyl disulfide
- heptanal
- butanal
- 2-butenal
- butanal
- 2-nonanone

- Control
- Lipid and protein oxidation increase with storage
Influence of spray drying

• Spray drying parameters influence flavor of high protein dairy products

• Lower pH produces lower flavor intensities and decreased aldehydes (whey protein only)

• Higher solids produces lower flavor intensities, decreased aldehydes and greater shelf stability (whey and milk proteins)

• Spray drying process increases flavor intensity of both protein types
  • No impact on solubility across pH or heat stability (p<0.05)
Sensory profiles of liquid and spray dried WPC80

- Aroma Intensity
- Sweet Aromatic
- Cardboard
- Astringency

Liquid and Powder comparison:
- Aroma Intensity: Liquid lower than Powder
- Sweet Aromatic: Liquid lower than Powder
- Cardboard: Liquid higher than Powder
- Astringency: Liquid lower than Powder
Selected aldehydes in liquid and spray dried WPC80

- Pentanal
- Hexanal
- Heptanal
- Octanal
- Nonanal
- Decanal

ppb
Sensory profiles of liquid and spray dried MPC80

- Aroma Intensity
- Sweet Aromatic
- Cooked Milky
- Cardboard
- Astringency

Liquid vs Powder
Selected aldehydes in liquid and spray dried MPC80

- Pentanal
- Hexanal
- Heptanal
- Octanal
- Nonanal
- Decanal

ppb
Increased powder storage time increases off flavors.

Shelf stability: WPC 80

PC1 38%  PC2 24%
Shelf stability: MPC 80

Biplot (axes F1 and F2: 85 %)

Increased time and storage temperature

Aroma Intensity

Sweet aromatic

cooked milky

Burnt sugar/gramham

tortilla

animal

cabbage

cardboard

Increased time and storage temperature

F2 (15 %)

F1 (70 %)
Solubility: MPC80

- 3C
- 25C
- 40C

Months

Percent Solubility

0 1 2 3 6 12
Summary

• Every step from milk to fluid whey to dried ingredients influences **functional and flavor** properties of dried dairy protein ingredients

• Careful selection and optimization of processing parameters can be applied to maximize flavor and functional quality
Comparison of Natural Sweeteners in Whey Protein Beverages
Background

- Consumer demand for naturally sweetened protein beverages with a low carbohydrate content (Gerdes, 2012; Jacobson, 2015; Oltman et al., 2015)
Alternative Sweeteners

• Synthetic non-nutritive sweeteners include saccharin, cyclamate, aspartame, sucralose, and advantame
  • Rejected by consumers as ‘unnatural,’ ‘unhealthy,’
• Natural non-nutritive sweeteners are most desired

Monk Fruit (*Siratia grosvenorii*)
Stevia (*Stevia rebaudian*)
Objectives

• Determine the effect of protein load (15g and 25g per 360 mL serving) on sweetness perception

• Compare natural non-nutritive sweeteners in protein beverages using temporal methods:
  • Time Intensity
  • Temporal Dominance of Sensations
  • Temporal Check-All-That-Apply
Protein Beverage Formulation Ready to Mix (RTM)

WPI
- 15g or 25 g PRO/360 mL serving

Water

Sweetener
- Sucrose
- Fructose
- Monk fruit
- Stevia
- Sucralose

Vanilla Flavored
Magnitude Estimation Scaling (MES)

- MES scaling used to determine iso-sweet concentrations of each sweetener to sucrose.
- Confirmed by trained panel and 2-AFC with 40 consumers.

- Results from MES are plotted with log (sweetener concentration) on the x-axis, and log (geometric mean of sweetener response) on the y-axis.

Taken from (Li et al., 2015).
Time Intensity (TI)

- Assessment of **sweet**, **bitter** and **metallic** tastes
  - Compusense Cloud software with iPads
- Intensity of a single attribute recorded over time (expectoration at 12s, evaluation through 142s)
- Conducted in triplicate by trained panelists (n=8)
Temporal Dominance of Sensations (TDS)

• Panelists evaluate multiple attributes at once and select the attribute they feel is dominant
• Shows the sequence of dominant sensations rather than intensities (Le Reverend et al., 2008)
• Conducted in quadruplicate (n=8)
• TDS Curves and Difference curves, chance level ($P_0$) calculated (Pineau et al., 2009)
Temporal Check-All-That-Apply (TCATA)

- Panelists evaluate and may select multiple attributes at once (Castura et al., 2015)
- Shows the evolution for various traits
- Conducted in quadruplicate (n=8)
- Similar analysis to TDS, Chance level ($P_0$) is calculated (Pineau et al., 2009)
Protein concentration had no effect on sweet taste perception

FRUCTOSE

SUCRALOSE

MONK FRUIT

STEVIA

25g protein  15 g protein
Sensory profiles of vanilla RTM protein beverages

Protein amount impacts other sensory properties

- Vanilla flavor
- Cardboard flavor
- Viscosity

15g/serving
25g/serving
Temporal differences
Sweet taste TI in RTM

![Temporal differences graph showing sweetness intensity over time for different sweeteners: STEVIA, MONK FRUIT, FRUCTOSE, SUCRALOSE, and SUCROSE.](image)
Temporal differences
Bitter taste TI in RTM

Bitter Intensity

STEVIA
MONK FRUIT
SUCRALOSE
FRUCTOSE
SUCROSE

TIME (seconds)
Temporal differences
Metallic taste TI in RTM

[Graph showing metallic taste intensity over time for various sweeteners: Stevia, Monk Fruit, Sucrose, and Fructose.]
Sucrose TDS Curves

Initial dominant sweet taste followed by sweet aromatic, and cardboard.
Stevia TDS Curves

Dominant and lingering bitter and metallic taste.
Sucrose: dominant Sweet taste and sweet Aromatic,

Monk fruit: lingering sweet taste and metallic dominant

TCATA curves for RTM beverages made With each sweetener

Stevia: lingering sweet, Metallic and bitter
Summary

• Protein amount had no impact on sweet taste perception *in neutral pH RTM*
  • Higher cardboard flavor with higher protein
  • Lower vanilla flavor
  • Higher viscosity

• Sweetener source had significant effects
  • Sucrose/fructose: clean, sweet
  • Sucralose: sweet, sl metallic
  • Monkfruit: sweet and metallic
  • Stevia: sweet, metallic, bitter

• Storage effects not evaluated
What about matrix?

- **Whey protein models**
- **11% w/w whey protein isolate**
  - Three texture types
    - Thin fluid
    - Thick fluid
    - Semi-solid
  - 2 sweeteners
    - Sucrose
    - Stevia

<table>
<thead>
<tr>
<th>Sample</th>
<th>Vanilla (%)</th>
<th>pH</th>
<th>Heat time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin fluid (F1)</td>
<td>1.5</td>
<td>6.9</td>
<td>0</td>
</tr>
<tr>
<td>Thick fluid (F2)</td>
<td>1.5</td>
<td>6.9</td>
<td>5</td>
</tr>
<tr>
<td>Semi-solid (SS)</td>
<td>1.5</td>
<td>6.9</td>
<td>9–12</td>
</tr>
</tbody>
</table>
Role of Matrix

- Order of magnitude difference between sweeteners
  - Stevia is sweeter
- **Increased sweetener required with thicker texture (both sweeteners)**
- Stevia has lower slope
  - Intensity is based on usage levels
  - Not related to sweet slope of sucrose
### EQUIVALENT SWEETNESS

<table>
<thead>
<tr>
<th>Sweetener</th>
<th>Thin fluid (F1)</th>
<th>Thick fluid (F2)</th>
<th>Semisolid (SS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sucrose</td>
<td>5.95b</td>
<td>6.02b</td>
<td>6.54a</td>
</tr>
<tr>
<td>Stevia</td>
<td>0.113b</td>
<td>0.112b</td>
<td>0.146a</td>
</tr>
</tbody>
</table>

- Semisolid requires greater sweetener concentration for iso-sweetness
Conclusions

• Significant challenges exist with formulating high protein foods (flavor is one challenge)

• An understanding of the challenges specific to the application AND the protein source is necessary

• Careful selection of proteins and formulation
Acknowledgements