Characterization of Functional and Sensory Properties of Select Commercial Food Protein Ingredients

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Wisconsin Center for Dairy Research
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Objective

✓ Characterize, compare, and contrast the functional and sensory properties of different commercially available dairy and plant protein ingredients
Protein in Study

**From US Suppliers**

- **Dairy Proteins**
  - **Milk Proteins**
    - Milk Protein Concentrate *(MPC80)* (3)
    - Milk Protein Isolate *(MPI)* (3)
    - Micellar Casein *(MCC)* (4)
  - **Whey Proteins**
    - Whey Protein Concentrate *(WPC80)* (3)
    - Whey Protein Isolate *(WPI)* (4)
    - Milk Derived Whey Protein *(NW)* (1)

**Suppliers/Distributors in US**

- **Plant Proteins**
  - **Potato Protein**-77-89% protein *(PoP)* (3)
  - **Pea Protein**-76-70% protein *(Pea)* (4)
  - **Soy Protein**-80-90% protein *(Soy)* (4)
  - **Rice Protein**-83% protein *(Rice)* (1)

**Protein Levels:** ~80-90%

**Total samples:** 30
Study Details

Functionality Testing
- Water Binding Capacity
- Viscosity
- Heat Stability at pH 3 and 7
- Emulsion Activity and Stability
- Foam Ability and Stability
- Gelation

Sensory Evaluation

Applications
- Beverages
  - Model beverage system (5% protein, pH 7, UHT)
  - Model beverage system (5% protein, pH 3, hot fill)
  - Sensory, Viscosity, Storage test
- Protein Bar
  - Model bar system (30% protein)
  - Sensory, Texture, Storage test
Functionality Tests

• Many ways to measure a functionality
  – Stick to one method per functionality

• Treat all protein ingredients in the same way
  – hydration (1 hr) at room temperature
  – Native pH

• Not to create optimal conditions
Water Holding Capacity

(*Means with different letters were significantly different (P <0.05).)

Milk ~ Soy ~ Pea > Whey ~ Potato ~ Rice

(Neumann et al., 1984)
Viscosity
(10% protein solution, room temp)

(*Means with different letters were significantly different (P <0.05).)

Milk ~ Pea > Whey ~ Potato ~ Rice

(Measured by Cannon - Fenske viscometer)
Heat Stability Index at pH 3

(5% protein solution, 85°C for 3 min, low amount of sediment: high heat stability)

Sediment (in mm)

<table>
<thead>
<tr>
<th>Protein</th>
<th>Sediment</th>
<th>Letters</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC</td>
<td>ab</td>
<td></td>
</tr>
<tr>
<td>MPI</td>
<td>ac</td>
<td></td>
</tr>
<tr>
<td>MCC</td>
<td>b</td>
<td></td>
</tr>
<tr>
<td>NW</td>
<td>df</td>
<td></td>
</tr>
<tr>
<td>WPI</td>
<td>e</td>
<td></td>
</tr>
<tr>
<td>WPC</td>
<td>ef</td>
<td></td>
</tr>
<tr>
<td>PoP</td>
<td>d</td>
<td></td>
</tr>
<tr>
<td>Pea</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td>Soy</td>
<td>cg</td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>dg</td>
<td></td>
</tr>
</tbody>
</table>

(*Means with different letters were significantly different (P < 0.05).)

Whey > Plant > Milk

(Harper and Lee, 1998)
Heat Stability Index at pH 7
(5% protein solution, 85°C for 3 min, low amount of sediment: high heat stability)

*Milk ~Whey > Plant*

(Harper and Lee, 1998)
Emulsion Activity
(5% protein solution : Oil = 1:1)

(*Means with different letters were significantly different (P < 0.05).)

Milk ~ Whey ~ Pea ~ Soy > Potato > Rice

(Dalev and Simeonova, 1995)
Emulsion Stability
(Heat @ 80°C for 30 min after emulsion was formed)

*Means with different letters were significantly different (P < 0.05).*

Milk ~ Pea ~ Soy > Whey > Potato > Rice

(Dalev and Simeonova, 1995)
Foaming Ability
(5% protein)

(*) Means with different letters were significantly different (P < 0.05).

Whey > Soy and Potato > Milk ~ Pea > Rice
Foam Stability

(*Means with different letters were significantly different (P <0.05).)

Whey > Milk ~ Soy ~ Potato > Pea > Rice
**Gel Strength**

(15% protein solution, heat @80°C for 45 min)

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Whey protein > Plant protein

(*Means with different letters were significantly different (P <0.05).*

(Measured by TA.XT Plus Texture Analyzer)
Sensory Properties
MaryAnne Drake, PhD,
North Carolina State University

- Sensory panel (9 people)
- Trained for more than 60 hrs
- Documented flavor properties using an established sensory language
Attribute Intensities
Flavor Differences between Plant and Dairy Proteins

**Plant Proteins**
- Cereal
- Sulfurous
- Beany
- Pyrazine/bell pepper
- Earthy/potting soil
- Fruity
- Sour aromatic
- Sour taste
- Umami taste

**Dairy Proteins**
- Cardboard
- Brothy
- Herbal/grassy
- Salty taste
- Bitter taste
- Astringency
- Sweet aromatic
- Milky/cooked
- Soapy
- Animal
- Tortilla

**Flavor Differences**

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  - Soapy
  - Animal
  - Tortilla
UHT 5% PROTEIN BEVERAGE

Produced at University of Minnesota
MicroThermics Unit
# Model UHT Beverage Formula

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtered Water</td>
<td>87.25*</td>
</tr>
<tr>
<td>Protein Ingredient</td>
<td>Standardize to 5% protein</td>
</tr>
<tr>
<td>Cane sugar</td>
<td>7.00</td>
</tr>
<tr>
<td>Natural Vanilla Flavor</td>
<td>0.50</td>
</tr>
<tr>
<td>Dipotassium phosphate</td>
<td>0.15</td>
</tr>
<tr>
<td>Gellan gum</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

* Adjusted according to protein content of protein ingredients
Procedure

• Mix in protein ingredients with a high speed mixer for 5 minutes in filtered water in stainless steel container.

• Hold container in warm water tank at 120°F (50°C) for one hour.

• Mix in flavor, phosphate and gellan gum for 2 minutes

• Measure pH and adjust to pH 7 with KOH.

• Process in UHT at 284°F (140°C) for 3 seconds

• Fill sterilized bottles in hood.
During Processing …

• 13 protein ingredients were selected based on heat stability results
  • Milk protein – 3
  • Whey protein – 3
  • Pea protein – 2
  • Soy Protein – 2
  • Potato Protein – 2
  • Rice Protein – 1
• 3 protein ingredients failed
  • 1 potato and 1 pea – Settled out
  • 1 potato protein – Blocked the equipment
Beverage Appearance & Flavor

- NW – Visible protein aggregates
- Flavor – Similar to sensory profile of protein ingredients
  - Dairy protein
    - Milky, Whey flavor
  - Plant protein
    - Beany, Astringency, Bitter
    - Rice – Sandy
- Formulation consideration
  - Color or flavor maskers
Viscosity of UHT Beverage (pH 7)
(Day1 vs. Storage test @ 45°C for 2wks)

Viscosity at Shear rate 1(s-Å¹)

(Measured by Kinexus Viscometer)
5% Protein High Acid Beverage

Processed in CDR Pilot Plant
# Model High Acid Beverage

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtered Water</td>
<td>87.07*</td>
</tr>
<tr>
<td>Protein ingredients</td>
<td>Standardize to 5% protein</td>
</tr>
<tr>
<td>Sugar</td>
<td>7.00</td>
</tr>
<tr>
<td>Green Mango WONF</td>
<td>0.20</td>
</tr>
<tr>
<td>85% Phosphoric Acid</td>
<td>0.73</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

* Adjusted according to protein content of the protein ingredients
Procedure

• Mix protein powder with filtered water with shear for 5 min
• Hydrate for 1h at room temperature
• Add sugar, flavor and phosphoric acid
• Adjust pH to 3.0
• Pasteurize at 180°F (82.2°C) for 2 min
• Bottle at 39°F (4 °C)
• Storage at 39°F (4 °C)
Beverage on Day 1 after Processing

- Whey protein
- RICE – Complete Separation
- Plant protein
- PEA 3 – Very Slight Separation
- Potato
- Soy
- Pea
- Others - No Visible Separation

NW1  WPI4  WPC2  POT1  SOY1  PEA3  RICE
**Sensory Screening**

<table>
<thead>
<tr>
<th>Beverage Sample</th>
<th>Descriptive Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW1</td>
<td>Astringent, Clean</td>
</tr>
<tr>
<td>WPI4</td>
<td>Astringent, Whey flavor</td>
</tr>
<tr>
<td>WPC2</td>
<td>The least astringent, Stale</td>
</tr>
<tr>
<td>POT1</td>
<td>The most astringent, Bitter, less intense mango flavor</td>
</tr>
<tr>
<td>SOY1</td>
<td>Astringent, Bitter, Stronger soy flavor (Beany) than mango flavor</td>
</tr>
<tr>
<td>PEA3</td>
<td>Astringent, The most bitter, Beany, No mango flavor</td>
</tr>
<tr>
<td>RICE1</td>
<td>Astringent, Bitter, Chalky, Sandy</td>
</tr>
</tbody>
</table>

- Beverage samples were tasted at 4°C
Refrigerated vs ST (Storage Test) @ Week 2

- Refrigerated samples – Stored at 4°C for 2 weeks
- ST samples – Stored at 45°C for 2 weeks
Viscosity of Hot Fill Beverage (pH 3)
(Day1 vs. Storage test @ 45˚C for 2wks)

- Means with different letters were significant difference (P<0.05)
- Viscosity was measured by kinexus viscometry at shear rate 1 /s at 4˚C
Model Protein Bar

CDR Application Lab
Model Bar Formulation
(Carb: Pro: Fat = 40:30:30)

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>% of calories</th>
<th>% in formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein Ingredient</td>
<td>30.0</td>
<td>33.0-39.5</td>
</tr>
<tr>
<td>Canola Oil*</td>
<td>30.0</td>
<td>8.8-14.9</td>
</tr>
<tr>
<td>Fructose syrup</td>
<td>40.0</td>
<td>52.0</td>
</tr>
</tbody>
</table>

* Adjusted according to protein content of the protein ingredient
Procedure

• 30 protein ingredients were used
• Mix ingredients in a Kitchen Aid Professional Mixer, for 30sec
• Weigh 25g of mixture into 1 ounce plastic cups
• Heat seal into metallized packages
• Store at room temp or in 45°C incubator
Bar Appearance
(Day 1 vs Room Temperature Storage Day 90)
Bar Hardness
(Day 1 vs 3 Months)

(Measured by TA.XT Plus Texture Analyzer)
Bar Appearance
(Day 1 vs Elevated Temperature Storage Day 30)
Bar Hardness
(Day 1 vs Elevated Temperature Storage Day 30)

(Measured by TA.XT Plus Texture Analyzer)
Summary of Study

• Dairy proteins (milk and whey protein) offer a comprehensive solution to end users
  – Functional testing: based on end use application and manufacturing process
  – Protein hydration: impact on functional properties
  – Large variability among food protein manufacturers within a protein category

• Dairy proteins offer a superior sensory experience
  – Plant protein: higher intensity on negative sensory attributes (beany, bitter, astringent, etc.)
Study to be continued …

- Collecting more plant protein ingredients
  - Almond protein
  - Chickpea protein
  - Canola protein
  - Lupine protein
- Possible combination of dairy and plant protein

Please contact us if you are willing to provide these samples.

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Susan Larson (slarson@cdr.wisc.edu)
Dairy and Plant Proteins

A New Era for Protein: Why U.S. Dairy Delivers in the Crowded Protein Marketplace

Thank You

- Global Food Forums
- Dairy Farmers of Wisconsin