Functions and Appeal of Plant-Based Proteins and Novel Proteins

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Demand for Protein

- The global protein demand for a population of 7.8 billion exceeds 200 million tons.
- The global demand for protein ingredients, including plant and animal sources, is expected to reach 7 million tons by 2025.
- The global protein ingredient market revenues are expected to reach 70 billion dollars by 2025, growing at rate of ~8% from 2014 to 2025.
- Plant protein ingredients account for ~40% of the global protein market.

http://nutritionsuccess.org/blog/2013/04/homemade-protein-boost-powder/
Demand for Protein on the Rise

• Population growth
• Socio-economic changes: rising income, increased urbanization, and aging population (protein is associated with healthy aging)
• Recognition of proteins role in a healthy diet
• Increases in demand for animal protein are seen in developing countries (global demand for animal-derived protein is expected to double by 2050 (FAO))
• Alternative protein demand is increasing in developed countries
Interest in Plant Protein

Reasons behind increased interest in plant proteins

• From consumers perspective
  – Growing interest in sustainable and environment friendly sources
  – Animal Welfare
  – Increased traction to plant-based and healthy diet
  – Vegetarians and flexitarians
  – Rising incidences of allergenicity

• From producers’ perspective
  – Addressing consumer demand
  – Seeking lower cost compared to traditional protein ingredients
  – Finding a unique and competitive place in the market
  – Valorizing by-products
  – Replacing chemical ingredients with functional proteins (clean label)

Population growth (10 billion by 2050)
Role of Proteins in Foods

- Nutritional contributions is a function of protein quality and quantity
- Essential amino acids and daily requirements (50g/day or 1g of protein/1 kg of body weight)
- Ease of digestion
- Physiological functionality
- Muscle growth/re-generation
  - Other benefits—reduce muscle deterioration in aging population, weight loss and metabolic health
  - Bioactive peptides: reduce hypertension, antidepressant, promote satiety
Physical functional properties

- **Color**
  - Light scattering – e.g. casein micelle
  - Chromophores – e.g. myoglobin in meat, betalains in red beets
  - Browning (non-enzymatic and enzymatic)

- **Flavor**
  - Hydrophobic a.a. – bitter
  - Acidic a.a. – sour
  - Cysteine – sulfur taste
  - Glutamate MSG – Umami flavor
  - Proteolysis
  - Sweetness
Role of Proteins in Foods

Physical functional properties

- Texture
  - Water-binding
  - Gelation/Coagulation
  - Solubility
  - Emulsifying
  - Foaming
  - Viscosity
  - Elasticity
Trendy Applications

- Meat analogues
- Protein beverages
- Dairy analogues
- Protein bars
- Extruded products

“According to market research, the plant-based meat sector is set to reach $5.2 billion by 2020 and could make up one-third of the market by 2050. This move away from meat is largely due to consumers’ rising concerns about animal welfare, personal health, and importantly, sustainability.”

http://www.onegreenplanet.org

https://www.statista.com/statistics
Protein Ingredients

Alternative Proteins Gaining Traction

• Pulses
  – PEAS
  – Chickpeas
  – Lentils
  – Beans
• Oilseeds
  – Canola (Rapeseed)
  – Sunflower
  – Camelina
  – Pennycress
• Single Cell Proteins
  – Yeast
  – Algae
  – Fungal (Mycoprotein)
• Lab grown proteins (cultured cells)
• Insect Protein
• Others
  – Oats
  – Hemp
  – Potato
  – Corn
  – Almonds
Peas: Trendy Source of Protein

• Benefits of growing field peas (*Pisum sativum*)
  – Has a short growing season
  – Fix nitrogen in the soil
  – Improve nutrient levels in the soil when added in the crop rotation

• Other advantages
  – Non-GMO
  – Low occurrence of allergenicity
Peas: Trendy Source of Protein

PEA PROTEIN GAINS GROUND IN US MARKET

Soy and pea protein as a percentage (%) of new food & beverage launches tracked with plant protein (US)

% of protein product launches

<table>
<thead>
<tr>
<th>Year</th>
<th>Soy</th>
<th>Pea</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>81.0</td>
<td>7.6</td>
</tr>
<tr>
<td>2013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>61.4</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>21.2</td>
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Peas: Trendy Source of Protein

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• Disadvantages
  - Lower PDCAAS compared to soy protein and animal protein
  - Inferior functionality
  - Flavor issues
  - Starch and fiber as byproducts after extracting the protein
Comparing Soy and Pea Protein

- Peas and soy contain similar proteins though in different proportions

<table>
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<th>Soy Proteins</th>
<th>Pea Proteins</th>
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<tbody>
<tr>
<td>Protein</td>
<td>% of Total Protein</td>
</tr>
<tr>
<td>Glycinin (11S)</td>
<td>38-51</td>
</tr>
<tr>
<td>β-conglycinin (7S)</td>
<td>28-41</td>
</tr>
<tr>
<td>Albumins</td>
<td>10-20</td>
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Linking Structure to Function

• Impact of surface hydrophobicity
  - Whey protein vs. plant protein solubility

![Whey protein Solubility curve](image1)

![Soy protein Solubility curve](image2)

![Bar chart](image3)
In the Way of Peas Getting Ahead

- Inferior functionality compared to soy protein
Linking Structure to Function

• Impact of conformation and surface properties
  – Emulsification: Casein vs. globular plant proteins

<table>
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<tr>
<th>Sodium Caseinate</th>
<th>Soy</th>
<th>Pea</th>
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<tr>
<td>At 0.5% protein has EC of 1800 g of oil per g of protein</td>
<td>At 1% protein has EC of 1500 g of oil per g of protein</td>
<td>At 2% protein has EC of 400 g of oil per g of protein</td>
</tr>
</tbody>
</table>

Exposed hydrophobic residues – high surface adsorption

Highly amphiphatic nature with distinct hydrophobic and hydrophilic clusters (regions) – makes them “Natural Emulsifier”
Linking Structure to Function

- Impact of protein profile
  - Protein gelation _ Soy vs. Pea

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<td>Albumins</td>
<td>~10</td>
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<td>Forms a gel at 10 % protein</td>
<td></td>
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Soy Protein

- Forms a gel at 10 % protein
- Forms a strong gel at 15% protein
- Does not form a gel at 10% protein
- Forms a weak gel at 15% protein

Pea Protein

- Forms a gel at 10 % protein
- Forms a strong gel at 15% protein
- Does not form a gel at 10% protein
- Forms a weak gel at 15% protein

Soy Protein: Glycinin, β-conglycinin, γ-conglycinin, Albumins, Convicilin, Legumin, Vicilin
Pea Protein: Glycinin, β-conglycinin, γ-conglycinin, Albumins, Convicilin, Legumin, Vicilin
Introducing Camelina and Pennycress

- Oilseeds in the *Brassicaceae family*
- Winter cover crops with environmental benefits including reduced soil and water erosion, reduced soil nitrate leaching, increased carbon sequestration, and reduced inputs of energy and pesticide
- Favored for short growing season, thus excellent for crop rotation
- Rich in both fat (30-40%) and protein (25-30%)
- Oil pressing leaves protein and fiber rich cake
Introducing Camelina and Pennycress

• Advantages
  ‒ Low occurrence of allergenicity
  ‒ Environmental benefits
  ‒ Acceptable PDCAAS (0.72 for PCP)

• Disadvantages
  ‒ Protein extraction challenges
  ‒ Inferior functionality
  ‒ Flavor issues
  ‒ Polyphenols and glucosinolates

Chopra et al. (2020) Nature Food 1:84; Chopra et al. unpublished
Hemp

- Belongs to the species *Cannabis sativa L*, which include marijuana, but the two plants are different
- Is bred to have less than 0.3% tetrahydrocannabinol (THC), an amount so little that they have no psychoactive effect when ingested
- A miracle crop, high in fat (30%) and protein (25%), grown for thousands of years
Hemp

• **Advantages**
  – Non-GMO
  – Can be used as a rotation crop, and can enrich the soil and prevent erosion
  – Pesticides are not required for hemp production, making cost of production low
  – Non-allergenic
  – Highly digestible

• **Disadvantages**
  – Lower PDCAAS compared to soy protein, due to lysine deficiency
  – Potentially inferior functionality
  – Not extensively researched
Areas to Be Addressed

• Understand how novel proteins can replace or be combined with traditional protein ingredients in various food products to deliver optimal nutrition, functionality, and flavor
• Determine viable (cost effective) extraction (wet and dry) and processing technologies for producing functional protein ingredients from novel sources
• Unveil unique characteristics and applications
• Investigate crop diversity and breed for protein quality traits
• Secure abundant and sustainable supply
Ways to Enhance Plant Protein Viability

- Optimize extraction methodology to maintain structural integrity, functionality, and nutritional quality
- Evaluate varietal differences and initiate breeding programs
- Flavor characterization
- Nutritional quality
- Functionalization
  - Targeted enzymatic modification
  - Maillard-induced glycation
  - Targeted fractionation
  - Non-thermal processing – cold plasma
Outcomes

- New, quality driven protein isolation protocols
- Economic prosperity for farmers and the food industry
- Feedback to the breeders
- Functionally enhanced protein isolates
SOT FDA Colloquia on Emerging Toxicological Science Challenges in Food and Ingredient Safety

New Plant-Based Foods and Proteins from Novel Sources

BREAK
Colloquium will resume at 10:30 ET