Plant Proteins
Opportunities, Challenges &
Tips for Successful Use in Formulations

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Edited version from the original presentation
Process development: Proteins, carbohydrates, oils, bioactive extracts
Pilot testing/ Process modelling
Toll processing
Analytical Services
Ingredient development/ sales

Saskatoon
Saskatchewan
Canada
Trends in Food, Nutrition & Health

10 Key Trends in Food, Nutrition & Health 2018

Reasons to Include More Plant-Based Food


(New Nutrition Business (http://www.fdin.org.uk)
### Consumers See Health Benefits in Plant-Based Proteins

% who strongly + somewhat agree

<table>
<thead>
<tr>
<th>Statement</th>
<th>Americans</th>
<th>Canadians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant-based protein is associated with positive health effects</td>
<td>46%</td>
<td>38%</td>
</tr>
<tr>
<td>Plant-based protein offers superior nutritional value compared to animal protein</td>
<td>17%</td>
<td>14%</td>
</tr>
<tr>
<td>There is no need to eat meat in today’s day and age</td>
<td>19%</td>
<td>17%</td>
</tr>
</tbody>
</table>

Trying to reduce meat consumption

(HealthFocus International)

- **60%**
- **43%**
- **39%**

Actively trying to eat plant-based foods

Data sources:
- Nielsen Product Insider, powered by Label Insight, 52 weeks ended July 8, 2017 (U.S.)
- Nielsen MarketTrack, National All Channels, 52 weeks ended April 29, 2017 (Canada)
Consumer Trends Shaping the Food Ecosystem 2018

Meal ingredients to meal solutions

Snacking – Traditional meals replaced by small meals/snacks

Food choices based on health and nutrition needs

Radical transparency and food with a story

(The 2018 Nourish Trend Report, Nourish Food Marketing)

Feeding the World

World population to reach 9.6 billion by 2050

Demand for food to be increased by 59-98% by 2050

Increasing number of flexitarians, vegetarian and vegans

## Target Consumers

### Different consumer groups demand different proteins

- Athletes, children, elders, etc.

### Majority of population growth in developing countries

- China, India, Africa
- Their food needs are different from consumers in developed countries

(From *World Population Prospects, 2012*).

### Increased middle class, especially in Asia

(Kharas, 2017)

### Millennials

(about 27% of global population)

(Kharas, 2017)
# Plant Protein Sources

## Cereals
- Wheat
- Corn
- Rice
- Oat
- Rye
- Barley

## Legumes
- Soybean
- Pea
- Lentil
- Chickpea
- Beans
- Lupin

## Oilseeds
- Canola
- Sunflower
- Hemp

## Ancient grains
- Quinoa
- Chia
- Teff
- Millet
- Sorghum

## Other
- Potato
- Algae
- Fungi (Mushroom)
- Yeast
- Nuts
- Leaves
Which protein?

**Commercialization considerations**
- Availability
- Supply chain and sustainability
- Affordability / Cost

**Nutritional and regulatory factors**
- Protein content
- Quality / PDCAAS
- Claims
- Allergenicity
- Safety / Anti-nutrients
- Product labeling and positioning
Most Demanding

PLANT-BASED POTENTIAL

+49% PLANT PROTEIN CLAIMS
+20% DAIRY ALTERNATIVES
+14% MEAT SUBSTITUTES

US$16.3bn
Forecasted global market for dairy alternative drinks in 2018.

Source: Innova Market Insights, 2017
Formulating with Plant Proteins

Taste, texture, appearance
- Pea protein has earthy notes, rice protein can be gritty
- Particle size affects texture, formulation
- Color

Functionality

Nutritional aspects

Value for co-products

Anti-nutrients

Raw material cost

Main Barriers
Variables at different stages of food production affect flavor, functionality, and quality

Growing/ Harvesting/ Storage

Extraction/ Fractionation/ Drying
Extraction and fractionation techniques
Equipment/ shear forces involved
Drying method

Formulation
Temperature, pH, mixing
Other ingredients in formulation

Further processing
Fermentation
Germination
Physical/ Chemical/ or enzymatic modification of proteins
Protein Ingredients

Dry Fractionated

- Dehulled, milled flours
  - 25-35 % protein
- Protein concentrates
  - 50-70 % protein
- Press cakes/ defatted meals
  - 30-50 % protein

Process

- Protein enrichment by separating fiber and starch fractions, or by expelling oil
- Dehulling, milling, air classification
- Pressing, sieving, de-oiling

Wet Fractionated

- Protein concentrates
  - 60-70 % protein
- Protein isolates
  - (acid precipitated/ membrane separated/ heat coagulated)
  - >80% protein

Fractionate protein, starch, fiber components mainly through wet processing
- Use of water, acid, alkali, salts, or solvents
- Spray dried or drum dried powders
## Protein Ingredients

<table>
<thead>
<tr>
<th>Dry Fractionated</th>
<th>Wet Fractionated</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Lower cost compared to wet processing</td>
<td>✓ Higher protein purity, better functionality</td>
</tr>
<tr>
<td>✓ Pre-concentration of protein and removal of impurities before wet fractionation</td>
<td>✓ Improved taste, color</td>
</tr>
<tr>
<td>× Seed properties affects separation and purity</td>
<td>✓ Less antinutrients</td>
</tr>
<tr>
<td>× Possible starch damage</td>
<td>× Higher water and energy usage/processing cost</td>
</tr>
<tr>
<td>× Higher oil and starch/oligosacharide contents can affect functionality</td>
<td>× Possible alteration of functionality due to pH/temperature changes</td>
</tr>
<tr>
<td>× Taste and color</td>
<td>× Loss of nutrients</td>
</tr>
<tr>
<td>× Antinutrients</td>
<td></td>
</tr>
</tbody>
</table>
## Protein Functionality in Food Formulation

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Property</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Techno-functional</td>
<td>Solubility</td>
<td>Solubility, Precipitation</td>
</tr>
<tr>
<td></td>
<td>Bulk rheology</td>
<td>Thickening, Gelling, Texturizing</td>
</tr>
<tr>
<td></td>
<td>Surface activity</td>
<td>Foaming, Emulsifying</td>
</tr>
<tr>
<td></td>
<td>Sensory</td>
<td>Binding of lipids/flavors</td>
</tr>
<tr>
<td>Bio-functional</td>
<td>Nutritional</td>
<td>Digestibility, Allergenicity</td>
</tr>
<tr>
<td></td>
<td>Physiological</td>
<td>ACE inhibition, Antioxidant, etc.</td>
</tr>
</tbody>
</table>
Molecular structure and functionalities of plant proteins are different from animal proteins
- meat, egg, milk
  - E.g. globular storage proteins from cereals, pulses, tubers vs structural and soluble proteins from animals

Different types of plant proteins have different molecular/structural properties
Factors Influencing Protein Functionality

<table>
<thead>
<tr>
<th>Structure</th>
<th>Environmental</th>
<th>Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.A composition</td>
<td>pH</td>
<td>Heat/Cool</td>
</tr>
<tr>
<td>Conformation</td>
<td>Salts</td>
<td>Pressure</td>
</tr>
<tr>
<td>Surface charge</td>
<td>Temperature</td>
<td>Shear forces</td>
</tr>
<tr>
<td>Surface properties</td>
<td>Solvents</td>
<td>Storage time</td>
</tr>
<tr>
<td>Reactive sites</td>
<td>Other ingredients</td>
<td></td>
</tr>
</tbody>
</table>

Depending on the application – certain functionalities are important to develop and maintain for product quality.
Further Processing – Functional Modifications

- Chemical modifications (acylation, succynilation)
- Enzymatic methods (hydrolysis, cross-linking)
- Extrusion/ Shear cell technology/ High pressure processing
- Fermentation
- Germination

Meat protein – fibrillar structure
Plant proteins – mainly globular

Unfolding of globular proteins and alignment of protein aggregates into fibrillar structures
**Structural alteration to obtain desired functionality!**
Further Processing – Functional Modifications

Plant proteins – mainly globular
Limited water solubility

Controlled enzymatic or chemical breakdown of globular proteins to improve solubility

Structural alteration to obtain desired functionality!
## Food Formulation - Functionality Needs

<table>
<thead>
<tr>
<th>Food</th>
<th>Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bakery</td>
<td>Matrix formation with viscoelasticity, water absorption, browning, heat denaturation, gelation, film formation, emulsification</td>
</tr>
<tr>
<td>Beverages</td>
<td>Solubility at wide pH range, heat stability, viscosity</td>
</tr>
<tr>
<td>Dairy products</td>
<td>Emulsification, foaming, viscosity, fat retention</td>
</tr>
<tr>
<td>Meat products</td>
<td>Gelation, emulsification, water/fat retention</td>
</tr>
<tr>
<td>Confectionary</td>
<td>Dispersibility, emulsification</td>
</tr>
</tbody>
</table>
## Protein Functionality – Assessment

<table>
<thead>
<tr>
<th></th>
<th>Soy-1</th>
<th>Soy-2</th>
<th>Soy-3</th>
<th>Egg albumin</th>
<th>Whey isolate (modified)</th>
<th>Pea protein</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water hydration</strong></td>
<td>3.91</td>
<td>2.79</td>
<td>4.59</td>
<td>0.752</td>
<td>0.99</td>
<td>3.22</td>
</tr>
<tr>
<td>(g water/g protein)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oil holding</strong></td>
<td>1.66</td>
<td>1.01</td>
<td>1.87</td>
<td>1.47</td>
<td>2.20</td>
<td>1.20</td>
</tr>
<tr>
<td>(g oil/g protein)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Emulsifying capacity</strong></td>
<td>163</td>
<td>104</td>
<td>254</td>
<td>204</td>
<td>210</td>
<td>155</td>
</tr>
<tr>
<td>(g oil/g protein)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Emulsion stability (%)</strong></td>
<td>100</td>
<td>100</td>
<td>94</td>
<td>100</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td><strong>Foaming capacity (%)</strong></td>
<td>210</td>
<td>220</td>
<td>80</td>
<td>91</td>
<td>244</td>
<td>130</td>
</tr>
<tr>
<td><strong>Foam stability (%)</strong></td>
<td>63</td>
<td>60</td>
<td>58</td>
<td>74</td>
<td>53</td>
<td>77</td>
</tr>
<tr>
<td><strong>Solubility (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH 2.0</td>
<td>25</td>
<td>24</td>
<td>28</td>
<td>95</td>
<td>103</td>
<td>55</td>
</tr>
<tr>
<td>pH 4.0</td>
<td>15</td>
<td>20</td>
<td>19</td>
<td>92</td>
<td>100</td>
<td>11</td>
</tr>
<tr>
<td>pH 5.0</td>
<td>17</td>
<td>22</td>
<td>16</td>
<td>84</td>
<td>102</td>
<td>11</td>
</tr>
<tr>
<td>pH 7.0</td>
<td>30</td>
<td>22</td>
<td>24</td>
<td>94</td>
<td>102</td>
<td>36</td>
</tr>
<tr>
<td>pH 10.0</td>
<td>55</td>
<td>30</td>
<td>35</td>
<td>90</td>
<td>99</td>
<td>54</td>
</tr>
</tbody>
</table>

Protein content of samples tested: Soy-1 (79.9%), Soy-2 (87.2%), Soy-3 (85.0%), egg (78.01%), Whey (89.6%), pea (80.02%)
Soybean

- Largest plant based protein source
  flour (50-65%), concentrates (65-90%), isolates (>90%), textured products
- Complete protein (PDCAAS 0.9 -1.0)
- Heart health, weight management, muscle health
- Composed of glycinin and β-conglycinin
  - Glycinin: Gelation, Emulsification
  - β-conglycinin: Elasticity
- Allergenicity

Functional properties and applications

- Good thickener, often unstable to heat and acids, good film forming and gelation ability – functionality depend on commercial protein type
- Applications – Beverages, nutrition bars, meat applications, meat replacers, bakery, snacks, cereals, pasta, soups, sauces, desserts
- Slight off-flavor (grassy/bitter- lipoxygenase, saponins, isoflavons)
Wheat

- Widely used plant based protein source
- Limited in lysine, low PDCAAS (whole wheat: 0.40, wheat gluten 0.25)
- Comprised of gliadin and glutenin
- Allergenicity

Functional properties and applications

- Poor water solubility, foaming and emulsification
- Excellent viscoelastic, thermosetting and water holding properties
- Applications: Bakery, cereals, bars, meat replacers
- Good flavour profile (combine with other protein)
- Lower in price
# Pulses

<table>
<thead>
<tr>
<th>Per 100 g</th>
<th>Chickpea flour*</th>
<th>Lentil flour*</th>
<th>Pea flour*</th>
<th>Pinto bean flour*</th>
<th>Faba bean flour**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein (g)</td>
<td>23</td>
<td>25</td>
<td>26</td>
<td>22</td>
<td>28</td>
</tr>
<tr>
<td>Fat (g)</td>
<td>6</td>
<td>2.5</td>
<td>2</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>59</td>
<td>62</td>
<td>62</td>
<td>67</td>
<td>55</td>
</tr>
<tr>
<td>Fiber (g)</td>
<td>13</td>
<td>20</td>
<td>17</td>
<td>14</td>
<td>24</td>
</tr>
</tbody>
</table>

*Source: USDA National Nutrient Database for Standard Reference, Release 24
**Internal data

- Compositional changes (variety differences)
- Inherent flavors
Pulse Protein Functionality and Quality

Functional properties and applications

- Gelling, structure, set characteristics, emulsification, encapsulation
- **Egg replacers** – e.g. pea, faba
- Baking, deep frying, pasta, soups
- Extrusion stability – snacks, meat products, meat replacers
- Pea protein - lower in price
- Faba, chickpea and lentil proteins – market introduction
- Beany off-flavors, bitterness
High moisture extrusion of pea protein

Pictures courtesy of Dr Shannon Hood-Niefer, Food Centre Saskatoon. [www.foodcentre.sk.ca](http://www.foodcentre.sk.ca)
Cereal/Pulse Combination

PDCAAS: Protein Digestibility Corrected Amino Acid Score

Source: Pulse Cereal Grains Partnership – Pulse Canada
Industrial Hemp (*Cannabis sativa* L.)

“the plants and plant parts of the genera Cannabis, the leaves and flowering heads of which do not contain more than 0.3 % (w/w) THC (tetrahydrocannabinol) including the derivatives of such plants and plant parts that contain no more than 10 μg/g (10 ppm) THC”

Hemp Proteins and Products in the Market

**Opportunity**

**Selection**

**Challenges**

**Applications**

**Takeaways**

CEREALS, SPORTS & SNACKS ARE KEY FOR HEMP NPD

Growth for leading market categories for hemp applications (Global, 2016 vs. 2015)

- **BAKERY**: +76%
- **SOFT DRINKS**: +39%
- **SPORTS NUTRITION**: +36%
- **SNACKS**: +9%
- **CEREALS**: +6%

PLANT-BASED HEMP PROTEIN SURGE

+28% increase in product launch activity containing hemp protein (Global, 2016 vs. 2015).

Whole seeds
Dehulled (hemp hearts)
Press cake and flours (30-50% protein)
Protein concentrates (60-70% protein)

Hemp Protein Functionality

**Functional properties and applications**
- Gelling, set characteristics, emulsification, egg replacer
- Soups, protein shakes, energy drinks, dessert, salad dressing
# Strategies for Overcoming Flavor Issues

<table>
<thead>
<tr>
<th>Minimize off-flavor formation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mask/reduce bitterness and off-flavor</strong></td>
</tr>
<tr>
<td>Increase sweet and salt tastes</td>
</tr>
<tr>
<td>Block tongue’s bitter receptors</td>
</tr>
<tr>
<td><strong>Avoid flavor “fade”</strong></td>
</tr>
<tr>
<td>Protein bind flavors, adjust accordingly</td>
</tr>
<tr>
<td><strong>Pairing up of flavors</strong></td>
</tr>
<tr>
<td>Beany notes with nut flavors, caramel or chocolate flavors</td>
</tr>
<tr>
<td>Astringency with citrus flavors</td>
</tr>
<tr>
<td>Bitter notes with chocolate or coffee flavors</td>
</tr>
<tr>
<td>Green notes with berry flavors</td>
</tr>
</tbody>
</table>

Source: Alan Rillorta, The ABCs of Formulating with Plant Proteins
## Strategies for Overcoming Texture Issues

<table>
<thead>
<tr>
<th>Use gums and modified starches to keep low-soluble proteins suspended</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Particle size</strong></td>
</tr>
<tr>
<td>Small size - smooth texture in beverages</td>
</tr>
<tr>
<td>More coarser texture for some cookie, bar applications</td>
</tr>
<tr>
<td><strong>Salt/ temperature/ pH control</strong></td>
</tr>
<tr>
<td>High salt, temperature, and pH closer to isoelectric point can precipitate proteins and change texture</td>
</tr>
</tbody>
</table>

Source: Alan Rillorta, The ABCs of Formulating with Plant Proteins
**Plant Protein Opportunity**

- Food formulation / Product concept
  - Source raw material / protein ingredient(s)
  - Process optimization
  - Functionality assessment
  - Functional modifications
  - Flavor assessment / improvement
  - Adjust food formulation for texture / flavor and functionality needs

**Challenges**

**Key Takeaways**

**Food formulation / Product concept**

- Source raw material / protein ingredient(s)
- Process optimization
- Functionality assessment
- Functional modifications
- Flavor assessment / improvement
- Adjust food formulation for texture / flavor and functionality needs

**Crave-worthy food product!**
Acknowledgements

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