Value-added processing and applications of oat proteins

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Global plant protein market

2010-2030 plant protein will grow by 43%

Health awareness

Sustainability
Global plant protein market

USD $8.35 billion in 2016
USD $14.22 billion in 2022
Global plant protein market

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
Health claim

- “Diets low in saturated fat and cholesterol that include 25g of soy protein a day may reduce the risk of heart disease” (US FDA, 1999).

- American Heart Association (AHA, 2000) endorsed the use of soy foods for people with elevated cholesterol.

- Protein claims: good source of protein, high in protein.
Food fortified with protein
U.S. Nutrient Content Claims (21CFR 101.54)

A food or beverage product may claim the following:

- “Added Protein”
- “Extra Protein”
- “Fortified with Protein”
- “Enriched in Protein”
- “More Protein”

…if it contains more-than 10% of the protein DRV value than the reference serving size of that food (RACC: Reference amounts customarily consumed per eating occasion) normally contains.

A food or beverage product may claim the following:

- “Good Source of Protein”
- “Contains Protein”
- “Provides Protein”

…if it contains more-than 10% of the DRV for protein (> 5g) per reference serving size (RACC).

A food or beverage product may claim the following:

- “Excellent Source” of Protein”
- “Rich Source of Protein”
- “High Source of Protein”

…if it contains more-than 20% of the DRV for protein (> 10g) per reference serving size (RACC).
Global plant protein market

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Source: Innova Market Insights, 2017
Plant protein product samples

Food and Beverages
Global plant protein market

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+20% DAIRY ALTERNATIVES

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Source: Innova Market Insights, 2017
Plant protein product samples
Plant protein product samples

Dietary supplements

Animal feed
Global plant protein market

ADM
Cargill
DuPont
Ingredion
Glanbia
Hampton Creek
Oats protein quality

- Availability (3 Million tonnes/year in Canada)
- Protein content (13-25%)- protein% comparable to pea for some variety
- Globulin protein as major protein component with good solubility and functional properties
- High quality (highest Lys) among cereal proteins, nearly equivalent in quality to soy protein (WHO)
- Tolerated by the majority of people suffering from celiac disease
- Neutral flavor and taste
### Oat protein functional properties

#### Egg and Dairy Protein Functionality

<table>
<thead>
<tr>
<th>Functionality Category</th>
<th>Oat Protein Functionality</th>
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<tbody>
<tr>
<td>Structure</td>
<td>Water control</td>
</tr>
<tr>
<td>Strength</td>
<td>Viscosity</td>
</tr>
<tr>
<td>Texture/mouthfeel</td>
<td>Flavor</td>
</tr>
<tr>
<td>Coloration</td>
<td>Opacity / turbidity</td>
</tr>
<tr>
<td>Emulsification</td>
<td>Particle suspension</td>
</tr>
<tr>
<td>Gelation</td>
<td>Adhesion</td>
</tr>
<tr>
<td>Film-forming</td>
<td>Agglomeration</td>
</tr>
<tr>
<td>Foaming</td>
<td></td>
</tr>
</tbody>
</table>
Protein gels in foods

Fat substitutes

Meat and fish binders

Meat analogues
Oat protein heat induced gels

OPI solution (15%, w/v) at pH 8

115°C, 15min
Oat protein gel texture

Soy: 2.1 – 2.6 N at neutral pH
Egg white: 8.70 N at pH 9
Oat protein gel water-holding capacity

Soy protein (82.2%)
Whey protein (~88%)
Oat protein heat induced gels

OPI solution (15%, w/v)

115°C, 15min

pH 8

Mechanical strength

Water-holding

Transparent/opaque

Oat gel network

Soy gel network
Oats protein networks

(a) Distribution of oat protein network sizes in nanometers. (b) AFM image of oat protein network in micrometers. (c) AFM image of oat protein network in micrometers. (d) AFM image of oat protein network in nanometers. (i) Schematic representation of oat protein network.
Oat protein-polysaccharide complex gel texture

<table>
<thead>
<tr>
<th>pH 2.5</th>
<th>pH 5</th>
<th>pH 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive stress (kPa)</td>
<td></td>
<td></td>
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<tr>
<td>OPI</td>
<td>1.53 ±0.27</td>
<td>10.19 ±1.32</td>
</tr>
<tr>
<td>OPI-I</td>
<td>1.47 ±0.11</td>
<td>9.63 ±1.03</td>
</tr>
<tr>
<td>OPI-I</td>
<td>2.07 ±0.31</td>
<td>10.92 ±2.12</td>
</tr>
<tr>
<td>OPI-I</td>
<td>2.19 ±0.38</td>
<td>14.16 ±2.85</td>
</tr>
</tbody>
</table>

Cohesiveness

<table>
<thead>
<tr>
<th>pH 2.5</th>
<th>pH 5</th>
<th>pH 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPI</td>
<td>0.41 ±0.03</td>
<td>0.67 ±0.01</td>
</tr>
<tr>
<td>OPI-I</td>
<td>0.47 ±0.06</td>
<td>0.63 ±0.07</td>
</tr>
<tr>
<td>OPI-I</td>
<td>0.39 ±0.04</td>
<td>0.70 ±0.02</td>
</tr>
<tr>
<td>OPI-I</td>
<td>0.26 ±0.03</td>
<td>0.68 ±0.05</td>
</tr>
</tbody>
</table>

Springiness (mm)

<table>
<thead>
<tr>
<th>pH 2.5</th>
<th>pH 5</th>
<th>pH 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPI</td>
<td>130.2 ±5.37</td>
<td>211.1 ±7.74</td>
</tr>
<tr>
<td>OPI-I</td>
<td>159.8 ±21.4</td>
<td>193.1 ±6.14</td>
</tr>
<tr>
<td>OPI-I</td>
<td>143.7 ±21.1</td>
<td>208.1 ±4.76</td>
</tr>
<tr>
<td>OPI-I</td>
<td>197.8 ±17.6</td>
<td>208.8 ±12.7</td>
</tr>
</tbody>
</table>

Gumminess (N)

<table>
<thead>
<tr>
<th>pH 2.5</th>
<th>pH 5</th>
<th>pH 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPI</td>
<td>0.08 ±0.01</td>
<td>0.90 ±0.09</td>
</tr>
<tr>
<td>OPI-I</td>
<td>0.09 ±0.02</td>
<td>0.80 ±0.10</td>
</tr>
<tr>
<td>OPI-I</td>
<td>0.10 ±0.02</td>
<td>0.94 ±0.15</td>
</tr>
<tr>
<td>OPI-I</td>
<td>0.08 ±0.01</td>
<td>1.16 ±0.13</td>
</tr>
</tbody>
</table>

Soy protein/gellan gum (~12.5 kPa)

Egg white: 22-32 kPa
Oat protein-polysaccharide binary gel microstructure

P H 2.5  P H 5  P H 7

a  b  c

d  e  f

g  h  i

Water holding capacity (%)
Gel formation mechanism study

- Increased interactions among protein by phase separation;
- Inulin performs a filling effect in the protein network;
- Localized interactions such as hydrogen and hydrophobic bonds may take place between protein and inulin at the phase borders.

Confocal microscopic photograms of oat protein gels with 0.5% inulin as a function of increasing temperature, scale bar 10 µm
Global plant protein market

**PLANT-BASED POTENTIAL**

- **+49%** PLANT PROTEIN CLAIMS
  - Global new product launches CGR 2013-2016

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

- **+20%** DAIRY ALTERNATIVES
  - Global new product launches CGR 2013-2016

- **+14%** MEAT SUBSTITUTES
  - Global new product launches CGR 2013-2016

Source: Innova Market Insights, 2017
Food application development of heat induced gels

Provide texture
Reduce oil uptake during frying

Veggie burger
Food application development of heat induced gels

Cross section of the cooked pork meat ball without (left) and with (right) oat protein gelling ingredient

Meat binder

Hardness 9.2N  Hardness 19.8N
Oat protein cold-gelation

Compressive stress:
23 kPa ~ 30 kPa

Egg white: 22-32 kPa

Preheated OPI solution
(7%, w/v) 115°C, 15min

Add Glucono-δ-lactone (GDL)

Cooling

pH 8

20 h

OPI gels
(OG7-3, 5, 10, 15)
Food application development of cold gels
Food application development of cold gels

- Protection of probiotics and enzyme

Fig. 3-5. (a) Survival ratio of probiotics in SGF. (b) Release of probiotics in SIF, (c) Activity of enzymes in SGF.

- Protecting enzymes and probiotics in harsh stomach condition;
- Controlled release of bioactive compounds.
Protein emulsions in foods

- Creamer
- Salade dressing
- Veggie mayonnaise
Non-dairy coffee creamer

- Good emulsifying capacity
- Good dispersibility
- No feathering
- Good whitening
- Neutral flavor

Oil (e.g. coconut oil)

Protein suspension

Homogenize

Spry-drying

Plant protein

Coffee creamer

Protein can attract to both oil and water thus allowing the two to mix to form emulsions
Global plant protein market

**PLANT-BASED POTENTIAL**

- **+49%** Plant protein claims (global new product launches, CASR 2012-2016)
- **US$16.3bn** Forecasted global market for dairy alternative drinks in 2018.

- **+20%** Dairy alternatives (global new product launches, CASR 2012-2016)
- **+14%** Meat substitutes (global new product launches, CASR 2012-2016)

Source: Innova Market Insights, 2017
Oat protein oil-binding and emulsifying property

Water (WHC) and oil binding (OHC) capacity of oat protein

Emulsion stability after centrifugation (ECS) and thermal treatment (ETS) of oat proteins
<table>
<thead>
<tr>
<th>Proteins</th>
<th>Emulsifying properties</th>
<th>Emulsion stability in coffee</th>
</tr>
</thead>
<tbody>
<tr>
<td>pea protein</td>
<td>Good</td>
<td>Feathering, flocculation happen after several minutes</td>
</tr>
<tr>
<td>Faba bean protein</td>
<td>Good</td>
<td>stability for &gt;2h</td>
</tr>
<tr>
<td>oat protein</td>
<td>Good</td>
<td>Feathering, flocculation happen after several minutes, after shaking no more flocculation appear</td>
</tr>
<tr>
<td>Canola protein fraction1</td>
<td>poor, phase separation happened in 5 minutes</td>
<td>stability for &gt;2h</td>
</tr>
<tr>
<td>Canola protein fraction2</td>
<td>Good</td>
<td>Feathering, flocculation happen immediately</td>
</tr>
</tbody>
</table>
## Protein emulsion properties in coffee

<table>
<thead>
<tr>
<th>Formula</th>
<th>Feathering*</th>
<th>Whitening**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faba bean protein: oil=1:1</td>
<td>No feathering</td>
<td>+</td>
</tr>
<tr>
<td>Faba bean protein: oil=1:2</td>
<td>No feathering</td>
<td>++</td>
</tr>
<tr>
<td>Faba bean protein: oil=1:3</td>
<td>Feathering after few minute</td>
<td>+++</td>
</tr>
<tr>
<td>Protein (FB:oat=1:1): oil = 1:1</td>
<td>Feathering</td>
<td>N/A</td>
</tr>
<tr>
<td>Protein (FB:oat=8:1): oil = 1:1</td>
<td>No feathering</td>
<td>++</td>
</tr>
<tr>
<td>Oat protein :oil =1:2</td>
<td>No feathering with 0.55% K$_2$HPO$_4$</td>
<td>++</td>
</tr>
</tbody>
</table>
## Spray-dried coffee creamer

<table>
<thead>
<tr>
<th>Treatments and proteins</th>
<th>Smell*</th>
<th>Colour**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faba bean proteins from machine dehulled Faba bean</td>
<td>XX</td>
<td>brown</td>
</tr>
<tr>
<td>Industrial deflavored Faba bean protein</td>
<td>X</td>
<td>light brown</td>
</tr>
<tr>
<td>Industrial deflavored pea protein</td>
<td>XX</td>
<td>yellow</td>
</tr>
<tr>
<td>oat protein</td>
<td>OK</td>
<td>light brown</td>
</tr>
<tr>
<td>Canola protein fraction</td>
<td>XX</td>
<td>brick red</td>
</tr>
</tbody>
</table>
Oat protein based coffee creamer
Oat protein based coffee creamer
Oat protein based coffee creamer
Oat beverage

• Globular protein as major protein component (good solubility) and high quality, nearly equivalent in quality to soy protein (WHO)

• High dietary fiber
Global plant protein market

Source: Innova Market Insights, 2017
α-amylase hydrolyses large, alpha-linked polysaccharides, such as starch and glycogen, yielding glucose and maltose.

Procedure:

1. preparing the suspension in deionised water at a temperature of 50°–53° C, pH at least 5, dry solids content of 10 - 15%.

2. centrifugation in order to remove coarse fibre particles (400 x g, 10-15 min).

3. treating the suspension with β-amylase and α-amylase (30 min. and 45 min.)

4. homogenising the enzyme-treated suspension at a temperature of 72°–75° C and a pressure of 200-250 bar.

oat flour

β-amylase releases successive maltose units from the end of a polysaccharide.
Oat beverage

- High protein + high beta-glucan
- Improve cost-effectiveness of the processing

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>OT3066</td>
<td>0</td>
<td>113</td>
<td>20.31</td>
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<tr>
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<td>19.70</td>
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<tr>
<td>OT3066</td>
<td>0</td>
<td>302</td>
<td>20.82</td>
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<tr>
<td>OT3066</td>
<td>150</td>
<td>116</td>
<td>20.76</td>
</tr>
<tr>
<td>OT3066</td>
<td>150</td>
<td>211</td>
<td>20.73</td>
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<tr>
<td>OT3066</td>
<td>150</td>
<td>307</td>
<td>20.63</td>
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<tr>
<td>OT3066</td>
<td>150</td>
<td>412</td>
<td>20.92</td>
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<tr>
<td>Morrison</td>
<td>0</td>
<td>105</td>
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<td>219</td>
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<tr>
<td>Morrison</td>
<td>0</td>
<td>311</td>
<td>21.45</td>
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<td>Morrison</td>
<td>150</td>
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<td>22.69</td>
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<tr>
<td>Morrison</td>
<td>150</td>
<td>403</td>
<td>22.33</td>
</tr>
<tr>
<td>Morrison</td>
<td>150</td>
<td>108</td>
<td>23.20</td>
</tr>
<tr>
<td>Morrison</td>
<td>150</td>
<td>202</td>
<td>22.73</td>
</tr>
</tbody>
</table>

Significantly different between fertilizer treatment (p<0.05)
## Oat beverage

- Protein + beta-glucan concentration
- Improve cost-effectiveness of the processing

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>Starch %</th>
<th>Proteins %</th>
<th>β-glucan %</th>
<th>Moisture %</th>
<th>Other carbohydrates and fat %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat flour</td>
<td>60.71 ± 2.22</td>
<td>13.70 ± 0.75</td>
<td>3.35 ± 0.62</td>
<td>5.61 ± 0.22</td>
<td>16.64</td>
</tr>
<tr>
<td><strong>Oat flour with reduced amount of starch</strong></td>
<td>39.69 ± 2.13</td>
<td>14.77 ± 0.75</td>
<td>9.40 ± 0.41</td>
<td>6.31 ± 0.12</td>
<td>29.84</td>
</tr>
<tr>
<td><strong>Starch from oat flour</strong></td>
<td>69.38 ± 3.09</td>
<td>7.46 ± 0.44</td>
<td>1.29 ± 0.05</td>
<td>6.68 ± 0.77</td>
<td>15.19</td>
</tr>
<tr>
<td><strong>Oat flour with reduced amount of starch</strong></td>
<td>7.38 ± 1.03</td>
<td>55.19 ± 0.88</td>
<td>8.88 ± 0.17</td>
<td>0.87 ± 0.04</td>
<td>27.68</td>
</tr>
<tr>
<td><strong>Starch from oat flour</strong></td>
<td>77.88 ± 3.20</td>
<td>4.01 ± 0.14</td>
<td>2.24 ± 0.08</td>
<td>0.97 ± 0.02</td>
<td>14.90</td>
</tr>
<tr>
<td><strong>Oat flour with reduced amount of starch</strong></td>
<td>5.29 ± 0.36</td>
<td>52.24 ± 0.61</td>
<td>13.89 ± 0.94</td>
<td>0.96 ± 0.05</td>
<td>27.62</td>
</tr>
</tbody>
</table>
Oat beverage

after 18 days
Storage stability of oat flour with reduced amount of starch

after 22 days
Other opportunities

Extrusion processing (left), and dry (middle) and cooked (right) oat noodles
Oat protein value-added opportunities
Mission

To create and develop competitive advantages for western Canadian crop resources in value-added product development with an emphasis on plant proteins
Research & Development Directions

**Feedstock**
- Characterize and understand feedstock attributes (different crops and varieties)
- Aligning crop component quality with product attributes demanded by market, identify and developing specialty crops for food and non-food applications

**Crop & By-Product Processing**
- Develop cost-effective processing to fractionate crop components.
- Advance technology to produce pure ingredients, extracts, and isolates from a wide range of Alberta based crops.
- Develop processing and utilization of by-product streams from primary processing and utilizing other supply sources: Distillers Grains, Brewing ingredients, barley leaves, straw, seed coats, hulls, etc.

**Property Testing**
- Evaluate unique properties and competitive advantages of crop extracts, isolates, and pure ingredients to predict their potential applications

**Value-Added Applications**
- Advancing technologies that convert crop components into value-added products for utilization within food, personal care, bioplastic, biomaterials, and other industrial applications
- Develop and customize the innovative technologies to meet specific industry requirements

**Services**
- Providing industry with access to expertise, unique analytical services, and problem solving capabilities
Collaboration and/or Investment

- Ongoing access to specialized expertise and skill sets
- Direct access to innovative and cutting edge research, and new intellectual property
- Direct access to state-of-the-art equipment and facilities
- Connections with ingredient suppliers and end users
Acknowledgement
Acknowledgement

Federal Government:

Canada Research Chair Program
Natural Sciences and Engineering
Research Council of Canada (NSERC)

Provincial Government:

- Alberta Crop Industry Development Fund.
- Alberta Innovates Bio Solutions

Industry partners

Prairie Oat Growers Association