Intermediate Wheatgrass: Food Science Work to Develop Applications

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University of Minnesota
Driven to Discover
What is Food Science and Why are We Working on IWG?

**Food science** is the study of the physical, biological, and chemical makeup of food; and the concepts underlying food processing. **Food technology** is the application of food science to the selection, preservation, processing, packaging, distribution, and use of safe food.

To Use Any Food Ingredient on an Industry Scale, we need to understand:

- **Functionality**
  - how do the protein and starch behave when we cook or bake with IWG?
  - Can we modify this through processing? Breeding for certain traits?
- **Storage stability**
  - What impacts shelf-life? Lipids? Enzymes?
  - Can we control this through processing?
- **Flavor**
  - How does it compare to other grains and products we know?
  - What is unique about it?
- **Nutrients**
  - What is its composition?
  - Are the unique components? Are there any anti-nutritional factors?
Benefits and Challenges of IWG - Composition of IWG Compared to Wheat

Composition IWG (average of 13 breeding populations)
- Carbohydrates: 71.5%
- Protein: 21.6%
- Ash: 2.7%
- Fat: 4.2%

Composition Whole Wheat (Hard red spring)
- Carbohydrates: 83.0%
- Protein: 12.0%
- Ash: 1.8%
- Fat: 3.1%

IWG (2004) 3.9 g/1000 seeds
More protein

Intermediate Wheatgrass (2015)
- Carbohydrate: 75.8%
- Protein: 16.4%
- Fat: 5.04%
- Ash: 2.30%

IWG (2015) 5.1 g/1000 seeds
More carbohydrates

HRW 26 g/1000 seeds
Importance of Protein & Starch for Product Functionality

- Proteins can be used to hold gas in baked goods (bread & popovers). Some products you want “strong” gluten, some you don’t (think bread flour vs. all-purpose flour).

- Starch is important for adding viscosity and to set products like cake.
- Also source of fermentable sugars.
Gluten

Gluten ELISA test strip confirming presence of gluten proteins in IWG

Protein patterns of wheat/IWG glutens by SDS-PAGE. Lane 1: protein marker; 2: whole wheat flour gluten; 3: Bulk IWG (Kernza); 4: IWG LI-1; 5: IWG LI-2; 6: IWG LI-3; 7: IWG LI-4; 8: IWG LI-5A; 9: IWG LI-5B

Just because IWG does not “form gluten”, and has some different proteins, does not mean it is not a wheat allergen. It is.
Challenge for Whole IWG flour in products that rely on protein to hold gas.

- Refined Bread Flour
- Whole Wheat Bread Flour
- Whole IWG Flour
Farinogram of Rouseau, MN grown IWG vs. Hard Red Wheat with various amounts of bran

Removing bran does not improve the gluten forming abilities
### Extensibility of IWG vs. Hard Red Wheat with various amounts of bran

<table>
<thead>
<tr>
<th>Bran (%)</th>
<th>Resistance to Extension (g)</th>
<th>Total Extensibility (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rosemount</td>
<td>Rousseau</td>
</tr>
<tr>
<td>0</td>
<td>22.33</td>
<td>32.86</td>
</tr>
<tr>
<td>25</td>
<td>19.2</td>
<td>27.25</td>
</tr>
<tr>
<td>50</td>
<td>17.43</td>
<td>24.96</td>
</tr>
<tr>
<td>75</td>
<td>15.25</td>
<td>22.95</td>
</tr>
<tr>
<td>100</td>
<td>14.3</td>
<td>19.56</td>
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</table>
IWG Flour Refining

Changes in protein secondary structure determined by ATR-FTIR

Complete refinement does not lead to the optimum ratio of $\beta$-turns to $\beta$-sheets.

75%_Bran_IWG has the best sheets/turns ratio suggesting a good compromise between dough extensibility and elasticity.
Ongoing work on strategies to improve functionality

• Continue looking at refinement (have done cookies & crackers, bread in progress)
• Dough conditioners
  – oxidizers (citric acid)
  – enzymes (xylanases, alpha amylase, transglutaminase)
Maybe Blending Isn’t So Bad?
Work by A. Marti, Jayne E. Bock, Maria Ambrogina Pagani, Koushik Seetharaman

Dough made at 70% Water Absorption
Blending whole grain IWG with refined HRW

Standard AACC method: AACC 10-05.01

Bread volume (cm³)

100% Wheat  50% Wheat  25% Wheat

Standard AACC method: AACC 74-09.01

Bread Firmness (N)

100% Wheat  50% Wheat  25% Wheat  100% IWG
IWG’s Carbohydrates

### Composition IWG (average of 13 breeding populations)
- Carbohydrates, 71.5%
- Protein, 21.6%
- Ash, 2.7%
- Fat, 4.2%

### Composition Whole Wheat (Hard red spring)
- Carbohydrates, 83.0%
- Protein, 12.0%
- Ash, 1.8%
- Fat, 3.1%

<table>
<thead>
<tr>
<th></th>
<th>% Fiber</th>
<th>% Starch</th>
</tr>
</thead>
<tbody>
<tr>
<td>IWG</td>
<td>15</td>
<td>67.4</td>
</tr>
<tr>
<td>Whole Wheat</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

More bran!

<table>
<thead>
<tr>
<th>Milling yield</th>
<th>% Bran</th>
<th>% Refined Flour</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>40</td>
<td>41</td>
</tr>
<tr>
<td>41</td>
<td>60</td>
<td></td>
</tr>
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</table>
Starch Pasting Profile

MVAG of blends with hard wheat
Less starch, lower peak viscosity
How can we improve IWG performance in cakes?
Used gluten-free strategies

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>White Wheat flour</td>
<td>IWG + Water</td>
<td>IWG + Water + albumin + xanthan</td>
<td>IWG + Water + albumin + xanthan + sorghum flour + arrowroot starch + potato starch</td>
<td>IWG + Water + albumin + xanthan + rice flour + potato starch</td>
<td>IWG + Water + albumin + xanthan + rice flour</td>
<td>IWG ++ Water + albumin + xanthan + rice flour</td>
</tr>
<tr>
<td></td>
<td>Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Albumin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Baking Powder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sugar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonfat Dried Milk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Salt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shortening</td>
<td></td>
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</tbody>
</table>
Things that improved Volume and Texture

- more water
- more egg white
- Xanthan gum helped with volume
- Different starches had different effects

Most preferred formula:
1.75X the water of control (moister, less gritty)
2x the albumin
+ rice flour
+ xanthan gum
Flavor

Toasted
- 2-acetyl-2-thiazoline
- 2-acetylpurine

Roasted
- 1-hexanol
- 2-phenylethanol
- Ethyl nonanoate
- 2-ethyl-3,5-dimethylpyrazine
- 2-ethyl-3,6-dimethylpyrazine

Rated higher in Whole Wheat
- Raisin: 2-methoxy-4-vinylphenol, salicylaldehyde
- Green: (E,Z)-2,6-nonadienal, 1-octen-3-ol, ethyl octanoate
- Bran: 1-hexanol, 2-phenylethanol, ethyl nonanoate

Rated higher in IWG
Great Nutritional Story!

<table>
<thead>
<tr>
<th>IWG (Avg of 13 breeding populations)</th>
<th>Whole Wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>ash 3%</td>
<td>fat 3%</td>
</tr>
<tr>
<td>fat 4%</td>
<td>protein 12%</td>
</tr>
<tr>
<td>protein 22%</td>
<td>ash 2%</td>
</tr>
<tr>
<td>carbs 71%</td>
<td>83%</td>
</tr>
</tbody>
</table>

more bran!

<table>
<thead>
<tr>
<th>% Fiber</th>
<th>21.8</th>
</tr>
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<tbody>
<tr>
<td>% Starch</td>
<td>47.7</td>
</tr>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>67.4</td>
</tr>
</tbody>
</table>
Dietary fiber (Whole grain flours, dry basis)
Storage Stability

- Main fatty acids: linoleic, oleic and palmitic acid (similar to wheat)
- Higher in carotenoids than wheat

<table>
<thead>
<tr>
<th></th>
<th>HRW</th>
<th>IWG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipoxygenase Activity</td>
<td>5.36*</td>
<td>5.00</td>
</tr>
<tr>
<td>Lipase Activity</td>
<td>1.84</td>
<td>2.79*</td>
</tr>
</tbody>
</table>

Heat treatment of groats/flour during processing may be used to inactivate problematic enzymes.
Results so far: Oxidative rancidity in IWG did not increase over accelerated storage compared to HRW, while hydrolytic rancidity increased slightly.
Factors Influencing Storage Stability: Antioxidant Content & Activity

<table>
<thead>
<tr>
<th>Sample</th>
<th>Hydroxycinnamic Acids (µg/g flour)</th>
<th>Carotenoids (mg/100g flour)</th>
<th>Antioxidant Activity (TEᵇ/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ferulic Acid</td>
<td>p-Coumaric Acid</td>
<td>Sinapic Acid</td>
</tr>
<tr>
<td>IWG</td>
<td>813*</td>
<td>20.4*</td>
<td>76.4*</td>
</tr>
<tr>
<td>HRW</td>
<td>506</td>
<td>7.00</td>
<td>50.0</td>
</tr>
</tbody>
</table>
Antioxidant activity (DPPH)

IWG populations

Trolox equivalents/g

2676 TE/g

1498 TE/g

1174 TE/g

C3-3486  C3-448  C3-214  Manifest  Manska  Oahe  HRW
Suggested Future Food Science Studies

- Processing
  - milling
    - tempering (time, temp)
    - type of mill
  - other processes
    - extrusion
    - flaking
    - puffing

- Chemistry
  - starch damage
  - effect of aging
  - fermentation

- Sensory characterization of flour and products at different refinement levels
  - Trained panels and consumer panels
Funding and Collaborators

- Initiative for Renewable Energy and the Environment (IREE)
- Forever Green Initiative (led by Dr. Donald Wyse)
- Minnesota Department of Agriculture
- The Land Institute

Collaborators:
- Dr. James Anderson and his research group at the University of Minnesota Agronomy/Plant Genetics Department
- Dr. Lee DeHaan (The Land Institute)
- North Dakota State University Wheat Quality and Carbohydrate Laboratory under Dr. Senay Simsek
- Dr. Alexandra Marti, University of Milan, Food Science, Agricultural Plant Science, Agronomy and Adjunct faculty member at UMN
- USDA-ARS Cereal Crops Research Unit under Dr. Jae-Bom Ohm