Wheat bran based insights and technologies for improving quality of bran rich cereal based products (Brantech and beyond)

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Aim of this presentation

• Provide context on the research we do on wheat bran
• Look into research on wheat bran properties with impact on product quality (Brantech and beyond)
Overview

- Context
- Wheat bran hydration properties
- Wheat bran associated enzymes
- Heat treatment of wheat bran
- Other applications
- Take home message

Context

- Increasing awareness of society and agro-food industry of the possibility and need to promote wellbeing through healthy and functional high quality food
- Dietary fibre should be an integral part of this type of foods, because of its impact on the gastro-intestinal tract
Focus on wheat bran (as ingredient or as part of whole meal) as source of dietary fibre
**Context**

- **Wheat bran:** typical chemical composition
  - Dietary fiber (43-62%)
    - Arabinoxylan (17-33%)
    - Cellulose (9-16%)
    - β-Glucan (7-9%)
    - Fructan (3-4%)
    - Lignin (3-10%)
  - Starch (6-30%)
  - Proteins (14-19%)
  - Minerals (5-8%)
  - Lipids (3-6%)
  - Vitamins

Based on data of Caprez et al., 1986; Zhang & Moore, 1997; Greffeuille et al., 2006; Seyer & Gélinas, 2009; Hemery et al., 2009.

**Milling fraction composition**

- **Coarse bran**
  - DV 18%
  - ZM 21%
  - Prot 6%
  - As 3%
  - Lipiden 5%
  - Andere 52%

- **Coarse wheatings**
  - DV 19%
  - ZM 20%
  - Prot 6%
  - As 4%
  - Lipiden 19%
  - Andere 43%

- **Fine wheatings**
  - DV 19%
  - ZM 31%
  - Prot 4%
  - As 5%
  - Lipiden 6%
  - Andere 40%

- **Low grade flour**
  - DV 19%
  - ZM 14%
  - Prot 6%
  - As 4%
  - Lipiden 19%
  - Andere 54%
Context

• **Wheat bran**
  - is the most *concentrated source of insoluble dietary fibre* in the European diet
  - consists of both *fermentable and non-fermentable fibre*
  - is *well-recognised* as a healthy food / feed constituent
    - EFSA recently approved *two health claims* for wheat bran in relation to beneficial physiological effects
    - Epidemiological studies also indicate that consumption of bran-rich products *reduces the risk of obesity, constipation, type 2 diabetes, cancer and cardiovascular disease*
  - is specifically colonised by communities of *microbiota* in the gut, including members of Clostridium cluster XIVa
Context

- **Wheat bran**
  - is available in large quantities in Europe (6.5 million MT)
  - price is low (~150 €/MT) compared to prices of (refined) insoluble (1,000 - 2,000 €/MT) and soluble dietary fibre (2,000 - 3,000 €/MT)
  - dry modifications can be performed at relatively low cost
    - Particle size reduction
    - Debranning of wheat prior to milling
    - Heat treatment
    - ...
  - In addition: does wheat bran as it comes from the mill lead to optimal nutritional and physiological effects?

Context

- **But... the use or presence of wheat bran brings along**
  - Serious technological and organoleptic drawbacks
  - Product structure and texture changes
  - Taste changes
  - Fresh keeping issues
  - Increased costs (high quality wheat, improvers)

- Can we find **bran based solutions** for these issues?
Context

• **Overall aim of research line on wheat bran**
  - To gain insight in the relationship between wheat bran structure, composition and properties and
    - its impact on processes
    - its impact on texture and organoleptic properties of end products
    - its nutritional and physiological properties
  - To use these insights to come to optimal wheat bran properties

⇒ **Basic knowledge on wheat bran properties is required**
Overview

- Context
- Wheat bran hydration properties
- Wheat bran associated enzymes
- Heat treatment of wheat bran
- Other applications
- Take home messages

Hydration properties of wheat bran

- **Aim: to gain insight in wheat bran hydration**
  - What is the effect of particle size reduction on hydration?
  - Which mechanisms govern wheat bran hydration?
Hydration properties of wheat bran

Literature

• **Hypotheses** regarding hydration properties
  
  o Excess water absorbed in bran enriched dough would lower the starch gelatinization temperature and decrease the final loaf volume (Dreese & Hoseney, 1982 and Rogers & Hoseney, 1982)
  
  o Arabinoxylan networks would draw water away from the gluten network causing inferior baking quality (Li et al., 2012)

• Despite these hypotheses, hydration properties of bran as such are not completely understood

• Hydration properties depend mostly on particle size but many contradicting observations exist (Auffret et al., 1994; Zhang & Moore, 1997; Rosell et al., 2006; Albers et al., 2009)

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Hydration properties of wheat bran

Literature

• Current reports on hydration properties of bran
  
  o Water retention capacity
    • Increases if particle size increases (Robertson & Eastwood, 1981; Mongeau & Brassard, 1982; Auffret, R et al. 1994; Zhang & Moore, 1997; Rosell, Santos et al. 2006)
  
  o Swelling capacity
    • Increases if particle size increases (Auffret, R et al. 1994; Rosell, Santos et al. 2006)

  o Enslin water absorption
    • Independent of size (Auffret, R et al., 1994)

  o Dough water absorption
    • Independent of size (Zhang & Moore, 1997; Campbell, Ross et al. 2008)
    • Increases if particle size increases (Albers et al., 2009)
    • Increases if particle size decreases (Sanz Penella et al., 2008)
Hydration properties of wheat bran
Sample preparation

- Milling of coarse wheat bran with Cyclotec 1093 mill

- Particle size distribution and average particle size

Hydration properties of wheat bran
Sample characteristics

- Physical properties: specific surface (N$_2$ physisorption)
  - Principle
  - Results

  Wheat flour: $0.45 \pm 0.05$ m$^2$/g
Hydration properties of wheat bran
Sample characteristics

• Other characteristics of interest

<table>
<thead>
<tr>
<th>Mean particle size (µm)</th>
<th>1687</th>
<th>1195</th>
<th>509</th>
<th>278</th>
<th>149</th>
<th>77</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific surface (m²/g)</td>
<td>0.38</td>
<td>0.44</td>
<td>0.45</td>
<td>0.57</td>
<td>0.63</td>
<td>0.72</td>
</tr>
<tr>
<td>Damaged starch (%)</td>
<td>0.87</td>
<td>0.95</td>
<td>1.01</td>
<td>1.16</td>
<td>1.10</td>
<td>1.19</td>
</tr>
<tr>
<td>Water extractable arabinxylan (%)</td>
<td>0.57</td>
<td>0.61</td>
<td>0.71</td>
<td>0.83</td>
<td>0.86</td>
<td>1.01</td>
</tr>
</tbody>
</table>

Hydration properties of wheat bran
Methods for hydration analysis

• Swelling capacity

• Water absorption
  Enslin-Neff device

• Water retention capacity
  Standard centrifugation

• Water retention capacity
  Drainage centrifugation

• Farinograph water absorption
Hydration properties of wheat bran

Hydration analysis: swelling capacity

- **Swelling capacity**

Hydration analysis: Enslin-Neff

- **Enslin-Neff water absorption**
Hydration properties of wheat bran
Hydration analysis: water retention capacity

- Water retention capacity - Standard centrifugation method

- Water retention capacity - Drainage centrifugation method
Hydration properties of wheat bran
Hydration analysis: water retention capacity

- Farinograph water absorption
  - Meal composition: 75% flour, 20% wheat bran, 5% gluten

Hydration properties of wheat bran
Analysis of results

<table>
<thead>
<tr>
<th>Method</th>
<th>Property of method</th>
<th>Hydration behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Swelling capacity</td>
<td>Bran not subjected to mechanical stress</td>
<td>Water uptake if size</td>
</tr>
<tr>
<td>• Enslin-Neff absorption</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mechanism
- Specific surface? ➔ No logical correlation
- Damaged starch & water extractable arabinoxylan? ➔ Differences too small to explain variation in hydration behavior
- Water uptake by intact matrix? ➔ Intact matrix of coarse bran absorb lots of water

KU LEUVEN
Hydration properties of wheat bran
Analysis of results

Mechanism
- Mechanical stress (centrifugal forces, mixing) causes bran matrix to release water
- Only strongly bound water remains absorbed

<table>
<thead>
<tr>
<th>Method</th>
<th>Property of method</th>
<th>Hydration behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water retention - Drainage centrifugation</td>
<td>Bran subjected to Centrifugal stress &amp; Mixing stress</td>
<td>No particle size effect</td>
</tr>
</tbody>
</table>

Method Property of method Hydration behavior

- Water retention - Standard centrifugation | Bran subjected to Centrifugal stress | Water uptake ↑ size ↑

Observation not in line with suggested hypothesis. Reason is reabsorption of water after centrifugation and before supernatant removal
Hydration properties of wheat bran

Water uptake is function of:
- Molecular binding (OH-H₂O)
- Nanopores
- Micropores
- Stacking effects

Conclusion

- Bran hydration can be governed by multiple mechanisms:
  - Particle stacking effects ~ large particles
  - Micropores filling ~ empty pericarp cells
  - Nanopores filling ~ cell wall matrix / cellulose structure
  - Molecular binding ~ H-bridges with OH groups carbohydrates

- The mechanisms which govern hydration in a practical situation dependent on the environmental conditions
  - Hydration in conditions without external force on bran
  - Hydration in conditions with external force on bran
Hydration properties of wheat bran
Relevance in bread making

• In bread making in the presence of wheat bran:
  o During mixing: only strongly bound water counts
  o During fermentation: matrix water can be expected to become important
    • Slow moisture redistribution in dough
    • Drying-up of dough during fermentation
  o During baking: slower bake-off of water
  o During bread storage:
    • Slow moisture redistribution in bread
    • Drying-up of dough during storage

• Reduction of particle size can be expected to reduce drying effects
Hydration properties of wheat bran
Relevance in bread making

- Wheat bran particle size reduction reduces mixing time
- At optimal mixing time and similar water absorption, wheat bran particle size reduction does not affect bread volume

Overview

- Context
- Wheat bran hydration properties
- Wheat bran associated enzymes
- Heat treatment of bran
- Other applications
- Take home messages
Wheat bran associated enzymes
Quantification of glycoside hydrolases

<table>
<thead>
<tr>
<th>Co-product</th>
<th>α-Amylase (U/g)</th>
<th>Endoxylanase (U/g)</th>
<th>Endopeptidase (U/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse bran 1</td>
<td>36.3</td>
<td>2.4</td>
<td>3.8</td>
</tr>
<tr>
<td>2</td>
<td>70.5</td>
<td>4.6</td>
<td>6.3</td>
</tr>
<tr>
<td>3</td>
<td>14.4</td>
<td>4.7</td>
<td>4.7</td>
</tr>
<tr>
<td>4</td>
<td>4.5</td>
<td>1.2</td>
<td>3.2</td>
</tr>
<tr>
<td>5</td>
<td>6.2</td>
<td>1.4</td>
<td>5.1</td>
</tr>
<tr>
<td>6</td>
<td>24.8</td>
<td>5.6</td>
<td>6.4</td>
</tr>
<tr>
<td>Coarse weatings 1</td>
<td>34.3</td>
<td>0.9</td>
<td>5.4</td>
</tr>
<tr>
<td>2</td>
<td>21.8</td>
<td>3.2</td>
<td>6.2</td>
</tr>
<tr>
<td>3</td>
<td>28.2</td>
<td>3.4</td>
<td>7.5</td>
</tr>
<tr>
<td>Fine weatings 1</td>
<td>17.7</td>
<td>0.7</td>
<td>4.1</td>
</tr>
<tr>
<td>2</td>
<td>29.1</td>
<td>2.0</td>
<td>6.2</td>
</tr>
<tr>
<td>3</td>
<td>14.2</td>
<td>1.0</td>
<td>5.9</td>
</tr>
<tr>
<td>4</td>
<td>20.0</td>
<td>2.6</td>
<td>6.6</td>
</tr>
<tr>
<td>Low grade flour</td>
<td>28.0</td>
<td>2.5</td>
<td>6.9</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>4.8</td>
<td>0.2</td>
<td>1.9</td>
</tr>
</tbody>
</table>

High variability in enzyme activities

Wheat bran associated enzymes
Relevance

- Relation between amylase units and Hagberg Falling Number (HFN) in a reconstituted meal:

5 U/g higher activity = HFN decrease of ± 30 s
10 U/g higher activity = HFN decrease of ± 70 s
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Wheat bran heat treatment

• Enzyme inactivation in hot air oven
• Baking trials with untreated and heat treated coarse bran

Heat treatment causes a shift in the volume - mixing time curve
Wheat bran heat treatment

- Enzyme inactivation in hot air oven
- Baking trials with untreated and heat treated coarse bran

Prehydration of heat treated bran counteracts this shift
Shift due to heat treatment probably related to changes in hydration properties

Wheat bran heat treatment
Hydration properties

- Effect of heat treatment on hydration properties
  - Swelling capacity and farinograph water absorption

Heat treatment does not affect water absorption at equilibrium
Effect of heat treatment on hydration properties

- Enslin water absorption
  
  - Coarse bran
  
  - Fine bran

Heat treatment seems to reduce the rate of hydration
Suggests an increase in hydrophobicity upon heat treatment

Contact angle goniometry – principle:
Measurement of contact angle between liquid and surface
- Liquid: H$_2$O
- Surface: Bran ~> coarse bran particle
Wheat bran heat treatment
Hydration properties

• Effect of heat treatment on hydration properties
  o Contact angle goniometry
    • Sample: coarse bran
      3 µL of water dropped on untreated bran: absorbed by bran
      3 µL of water dropped on heat-treated bran: repelled by bran
  o Sample: $d_{av}$ 1687µm, heat treated

Wheat bran heat treatment
Hydration properties

• Effect of heat treatment on hydration properties
  o Contact angle goniometry – CAM 200 goniometer (KSV Instruments):
    Comparison of initial contact angles between water and regular & heat treated bran:
Wheat bran heat treatment
Conclusion

- **Baking trials with untreated and heat treated coarse bran**
  - Heat treatment caused a shift in volume - mixing time curve which could be counteracted by bran prehydration
  - Link with observed increase in bran hydrophobicity:
    - Proper dough development requires sufficient water uptake by meal
    - Insufficient hydration will result in excess of free, unbound water
    - Excess water gives sticky, underdeveloped dough and low loaf volume
  - At relative short mixing times meals containing heat treated bran will absorb relatively less water and give rise to sticky underdeveloped dough and low loaf volume. Increased (mixing) times are required to obtain similar volumes

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Pearling of wheat prior to milling

Microscopy

Unpearled kernel
Pearling of wheat prior to milling

Microscopy

12% pearled
→ Inhomogeneous process

Pearling of wheat prior to milling

Bread making

Same content non-endosperm material
Bran / pearling

Same total starch content

Water absorption
Farinograph

Mixing time
Mixograph

Bread making (100 g)

Volume
Pearling of wheat prior to milling

**Bread making**

- Impact on bread volume:

  ![Bar chart showing the effect of pearling on bread volume](chart.png)

  - Least negative effect with aleurone pearling fractions

**Cake making**

- Coarse & fine bran
- P0-3% & P6-9%
- Untreated and heat treated

**Bran in cake**

**Approach**

- Same total starch content
- Same content non-endosperm material
- Standard cake procedure
Bran in cake

**Impact of bran on cake volume**

- Bran particle size determines cake volume
- Type of tissue is less determining for cake volume

![Graph showing impact of bran on cake volume](image1)

Bran in cake

**Impact of bran on cake crumb texture**

- Crumb hardness: no straightforward conclusion
- But: springiness, cohesiveness and resilience mainly depend on type of tissue
  - Eg. Springiness:

![Graph showing impact of bran on cake crumb texture](image2)
Bran in cookies

**Approach**

- Coarse & fine bran
- P0-3% & P6-9%
- Untreated and heat treated

**Same total starch content**

**Same content non-endosperm material**

**Standard cookie procedure**

**Dimensions**

**Break strength**

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**Bran in cookies**

**Impact of bran on cookie dimensions**

- Higher cookie height upon bran incorporation
- Diameter depends on particle size and type of tissue
Bran in cookies

**Impact of bran on cookie volume**

- Incorporation of coarse bran leads to less dense cookies
- Extra structure formation through coarse particles?

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**Bran in cookies**

**Impact of bran on cookie break strength**

- Break strength determined by tissue type
  - Bran rich cookies seem to bend, rather than to break
Overview

• Context
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Take home messages

• Wheat bran consumption is beneficial (as ingredient or part of whole meal)

• Finding wheat bran based solutions to problems related with bran incorporation in cereal based systems requires in depth knowledge of wheat bran properties and of the system: sometimes back to basics