WHEAT MILLING QUALITY: INFLUENCING FACTORS AND NEW METHOD OF ASSESSMENT

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Outline

1. Definition & factors of wheat milling quality
2. Development of a new test mill
Milling Quality

Ability to produce high yield of flour without contamination by peripheral tissues

- Milling Yield
- Milling Energy
- Flour Purity

- Percentage of starchy endosperm recovered
- Percentage of peripheral tissues incorporated
Factors of Milling Quality

• Extrinsic factors (commercial quality)
  – Impurities, moisture content, broken kernels, ...

• Regulation factors (regulatory quality)
  – Ash content of wheat and distribution of minerals within the grain

• Intrinsic factors (technological quality)
  – Endosperm to hulls ratio
  – Endosperm texture: hardness and vitreousness
  – Easyness to separate endosperm from bran
Intrinsic Factors of the Milling Quality

Milling Value

Endosperm Texture

Separability Endosperm to hulls

Ratio
Endosperm/outer layers
Endosperm to Outer Layers Ratio

- Estimation of the flour/bran yield potential
- Not easy to determine:
  - Traditional methods: Grain size, Test weight
  - New physical methods
  - New biochemical methods
Morphological Measurements

Extraction of morphological features

Comparison of the model with real grain sections

3D parametric modelling of the grain

Use of the model for surface & volume determination

Endosperm estimated volume (mm³)

Flour Yield (%dm)

\[ V_{\text{tot}} - V_{\text{bran}} = V_{\text{endosperm}} \]

Estimation of the voluminal milling yield

\[ R^2 = 0.79 \]
Molecular Approach

Tissue proportion =

\[
100 \times \frac{[\text{Marker}]_{\text{grain}}}{[\text{Marker}]_{\text{dissected tissue}}}
\]
Predicting Milling Yield Using Biochemical Markers

<table>
<thead>
<tr>
<th></th>
<th>Pericarp (%DM)</th>
<th>Interm. layer (%DM)</th>
<th>Aleurone (%DM)</th>
<th>Embry. axis (%DM)</th>
<th>Peripher. tissues (% d.m.)</th>
<th>Bran Yield (%DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.4</td>
<td>3.1</td>
<td>6.9</td>
<td>1.0</td>
<td>14.4</td>
<td>16.4</td>
</tr>
<tr>
<td>B</td>
<td>3.9</td>
<td>3.4</td>
<td>6.9</td>
<td>0.9</td>
<td>15.1</td>
<td>16.7</td>
</tr>
<tr>
<td>C</td>
<td>4.0</td>
<td>2.0</td>
<td>8.5</td>
<td>1.0</td>
<td>15.4</td>
<td>15.5</td>
</tr>
<tr>
<td>D</td>
<td>4.1</td>
<td>2.8</td>
<td>7.9</td>
<td>1.1</td>
<td>15.9</td>
<td>17.6</td>
</tr>
</tbody>
</table>
Intrinsic Factors of the Milling Quality

Endosperm/Outer Layers Ratio

Milling Value

Endosperm Texture

Separability Endosperm to hulls
# Endosperm Texture

<table>
<thead>
<tr>
<th>Hardness</th>
<th>Vitreousness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard / soft</td>
<td>Vitreous/ floury</td>
</tr>
<tr>
<td>Physical</td>
<td>Optical</td>
</tr>
<tr>
<td>Genetic</td>
<td>Agronomy</td>
</tr>
</tbody>
</table>

How hardness and vitreousness affect milling behaviour?
Some differences between hard and soft wheat types

Larger differences within a same wheat type
## Impact of Hardness on Milling Behavior

<table>
<thead>
<tr>
<th></th>
<th>Hard</th>
<th>Soft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break Flour</td>
<td>-</td>
<td>+++</td>
</tr>
<tr>
<td>Sizing Flour</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Reduction Flour</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Semolina Production</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>Large Bran / Total bran</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Total flour yield</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
Granulometry of Reduction Streams

- Volume %
- Granulometry (µm)
- Hardness
- Vitreousness

Graph showing the granulometry of flour and farina with volume percentages and hardness values plotted against granulometry (µm).
Mechanical Properties of Endosperm

Hard and vitreous: ↑ extensibility

↑ Hardness = ↑ Failure Stress

Mechanical properties of endosperm = Indicator of easyness of endosperm to be reduced into flour
EBA depends on vitreousness

For a same hardness class and a same vitreousness level, some varieties deliver flour more easily
Endosperm Texture

• Endosperm texture strongly affects milling behaviour but not the milling efficiency
• Milling energy to reduce endosperm into flour depends either on hardness and vitreousness
• Hardness determines the free starch granule in flour whereas vitreousness is more influential for the flour/farina ratio
• Vitreousness impacts on mechanical properties of hard endosperm: fragile to ductile
• Molecular markors are available for hardness: PIN
• Which factors are involved in the modulation of the endosperm reduction rate?
Intrinsic Factors of the Milling Quality

Endosperm Texture

Separability Endosperm to hulls

Ratio
Endosperm/Outer Layers

Milling Value
Concept of Separability

Milling Yield

Loss of endosperm in bran fraction

Bran contamination in Flour fractions

Flour

Bran / Shorts

Purity
Separability Index

\[ SI = (\%E) - [(\%A) + (\%P)] \]

Relative proportions of extracted:
- Endosperm (\%E)
- Aleurone (\%A)
- Pericarp (\%P)

Loss of Endosperm in Bran (% d.m.)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Loss of Endosperm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.2</td>
</tr>
<tr>
<td>B</td>
<td>4.8</td>
</tr>
<tr>
<td>C</td>
<td>5.6</td>
</tr>
<tr>
<td>D</td>
<td>4.4</td>
</tr>
<tr>
<td>E</td>
<td>3.7</td>
</tr>
</tbody>
</table>

Contamination with Aleurone Cell Walls (% d.m.)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21.8</td>
</tr>
<tr>
<td>B</td>
<td>9.5</td>
</tr>
<tr>
<td>C</td>
<td>9.3</td>
</tr>
<tr>
<td>D</td>
<td>17.4</td>
</tr>
<tr>
<td>E</td>
<td>21.2</td>
</tr>
</tbody>
</table>
Endosperm-Bran Separability Influencing Factors

Bran contamination in Flour fractions

Bran friability

Flour

Bran/shorts
Mechanical Properties of Grain Hulls

Transverse Orientation

Longitudinal orientation

Controls T and RH

Aleurone

Traction Tests

Péricarp

Testa
Mechanical Properties of Hulls

Large variability between hard and soft wheats and within each type of heat
Influence of Cell Wall Polysaccharide Organization on Mechanical Properties

Degree of arabinoxylan cross-linking in the cell wall

\[ \text{DHD} = \frac{\text{Xyl}}{\text{Xyl}} \]
Bran Contamination into Flours

• Breaking stage leads to cellular fractionation of the aleurone layer and hard wheat flours are more enriched in aleurone cell content
• Aleurone enrichment in flour depends on the mechanical properties of hulls (extensibility)
• Mechanicals properties of hulls exhibit a large variabilty
• At molecular level, hulls extensibility could be related to the degree of arabinoxylans cross-links
Influencing factors for endosperm-bran separability

Adhesion of endosperm on the aleurone layer

Loss of endosperm in bran fraction

Flour

Bran/shorts
Bran Internal View

Soft

Hard
Adhesion Between Wheat Tissues

- Adhesion force between tissues
- Local composition analysis

Peeling tests  Pulsed-Laser Ablation  Atomic-Force Microscopy

- Raman Microscopy  Immunolocalization

Endosperm-aleurone border Jääskeläinen et al., 2013, INRA, BIA
Predicting the Milling Quality

• Several influencing factors affect milling operations, milling yield and flour purity
• Influencing factors may interact
• All these factors must be taken into account to develop a milling test.
2. Development of a New Test Mill

**Aims**

- To predict the milling quality of wheat cultivars from less than 1kg
- To describe the wheat milling behaviour: Break flour yield, reduction flour yield, bran finishing, flour purity, ...
- To obtain a flour whose quality allows to conduct subsequent tests: rheology, breadmaking test, ...
The New Chopin Lab-Mill
- 500 g of wheat implemented,
- Tempering wheat to 16 % (H2O)
- 2 breaking stages B1 and B2 with flour extraction 180 µm,
- 2 Reduction stages CL and C
- 5 end-products: break flour, reduction flour, large and fine brans and shorts.
Some New Features

1. Precise and automatic feed rate control
2. Roll speed control
3. Adjustable roll gaps
4. Improved centrifuge sifting
Performances of the New Chopin Lab-Mill

• Comparison of milling performances with a reference mill
• Variability of wheat milling efficiency
• Flour quality
Prediction of the Milling Yield

- 10 samples were not well predicted = 87.5% with a good prediction
- 15% under estimated
- 21% over-estimated
- 64% well predicted

Regression slope = 1
Prediction of Bran Ash Content

Reference Mill vs. Chopin Test-Mill

$y = 0.94x + 1.7$

$R^2 = 0.80$
Flour Ash Content

Estimation with NIR measurement

\[ y = 0.9937x \]

\[ R^2 = 0.9405 \]
Reliability of the Chopin Test-Mill

Average milling yield: 75.1%

<table>
<thead>
<tr>
<th>Issues</th>
<th>Average Value</th>
<th>Standard Deviation</th>
<th>C.V. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% FB1</td>
<td>16.8</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>% FB2</td>
<td>11.7</td>
<td>0.1</td>
<td>1.1</td>
</tr>
<tr>
<td>% FC1</td>
<td>33.0</td>
<td>0.4</td>
<td>1.0</td>
</tr>
<tr>
<td>% FC2</td>
<td>5.4</td>
<td>0.2</td>
<td>3.4</td>
</tr>
<tr>
<td>% L bran</td>
<td>11.7</td>
<td>0.4</td>
<td>3.4</td>
</tr>
<tr>
<td>% F bran</td>
<td>5.8</td>
<td>0.2</td>
<td>4.0</td>
</tr>
<tr>
<td>% Shorts</td>
<td>6.2</td>
<td>0.2</td>
<td>2.4</td>
</tr>
<tr>
<td>% Total Flour</td>
<td>75.7</td>
<td>0.2</td>
<td>2</td>
</tr>
</tbody>
</table>

A reliable tool on a large set of samples and with different operators.
A large experimental network
50 cultivars, 9 locations,
- 2 years
- 2 nitrogen levels (with and without complementary contribution of 50 units)
Choice of 32 varieties of 4 DNA groups of PIN b+ (soft, b, c and d) and of 8 growing conditions
### Genetic Variability of Milling Efficiency

#### Hard Type

<table>
<thead>
<tr>
<th>Milling Yield &gt; 79 %</th>
<th>Milling Yield</th>
<th>Milling Yield &lt; 76.8 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soissons (80.1)</td>
<td>Apache (79.7)</td>
<td>Carenius (76.8)</td>
</tr>
<tr>
<td>Euclide (80)</td>
<td>Isengrain (79.5)</td>
<td>Oackley (76.6)</td>
</tr>
<tr>
<td>Perfector (79.1)</td>
<td>Bermude (79)</td>
<td>Orvantis (76.4)</td>
</tr>
<tr>
<td>Crousty (20)</td>
<td></td>
<td>Quebon (75.1)</td>
</tr>
<tr>
<td>Robigus (15.5)</td>
<td></td>
<td>Timber (75.5)</td>
</tr>
<tr>
<td>Ressor (15.5)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Soft Type

<table>
<thead>
<tr>
<th>Cultivar (Hardness)</th>
<th>Total Flour (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crousty (20)</td>
<td>77.1</td>
</tr>
<tr>
<td>Robigus (15.5)</td>
<td>76.1</td>
</tr>
<tr>
<td>Ressor (15.5)</td>
<td>75.9</td>
</tr>
<tr>
<td>SC 4013 (31)</td>
<td>74.75</td>
</tr>
<tr>
<td>Paledor (10.3)</td>
<td>74.75</td>
</tr>
<tr>
<td>Astuce (13.4)</td>
<td>74</td>
</tr>
<tr>
<td>Innov (6)</td>
<td>71.4</td>
</tr>
</tbody>
</table>

**Milling Yield > 79 %:**
- All others

**Milling Yield < 76.8 %:**
- Carenius (76.8)
- Oackley (76.6)
- Orvantis (76.4)
- Quebon (75.1)
- Timber (75.5)
Alveographic Properties of the flour obtained with the Chopin Test-Mill

<table>
<thead>
<tr>
<th></th>
<th>W</th>
<th>G</th>
<th>P/L</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Origin</td>
<td>SD</td>
<td>moy</td>
</tr>
<tr>
<td>Soft</td>
<td>N+</td>
<td>133</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>103</td>
<td>6</td>
</tr>
<tr>
<td>b</td>
<td>N+</td>
<td>256</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>254</td>
<td>75</td>
</tr>
<tr>
<td>c</td>
<td>N+</td>
<td>238</td>
<td>97</td>
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<tr>
<td></td>
<td>N</td>
<td>174</td>
<td>51</td>
</tr>
<tr>
<td>d</td>
<td>N+</td>
<td>225</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>164</td>
<td>85</td>
</tr>
</tbody>
</table>
Summary

• Milling quality is a key factor within the cereal chain

• There exist large differences of milling quality among wheats: cultivars, endosperm texture, growing conditions,...

• Establishing the structural basis of milling efficiency needs a multiscale approach in order to take into account several factors: morphological, anatomical, mechanical, biochemical, ....

• Recent data highlights some grain properties as crucial factors: hulls extensibility, endosperm breakage ability

• A new Lab-Mill has been developed to propose a fast screening system to answer breeders demand as well as for grading systems and millers requirements.
Acknowledgements

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