MILLING TECHNOLOGY FOR CEREALS

Filip Van Bockstaele, 16-05-2017, QAQC training on flour fortification, Lusaka, Zambia
CEREALS
WHAT ARE CEREALS?

- Ceres
- Grass family (Gramineae)
  - One seeded fruits
    - Caryopsis = kernel = grain
      - Germ
      - Endosperm
    - Bran: seed coat and fruit coat
      - Developes in glume (chaff, husk)
GENERAL ASPECTS

- Easy to cultivate
- High yield
- Stable when not processed
- Both in moderate as in dry climates
- Storage in dry conditions

- Insect and rodents cause major losses
- Mycotoxins are a food safety issue
- Spoilage is mostly caused by moulds
CEREALS IN THE WORLD

Annual production of major cereals in 2010/2014

(Estimated in Million tonnes, based on faostat.fao.org)
NUTRITIONAL IMPORTANCE OF CEREALS

- Macronutrients:
  - Carbohydrates (50-80%)
    - Staple food
  - Digestable: starch
  - Undigestable: dietary fiber
  - Proteins (8-15%)
  - Lipids (1.5-7%)

- Micronutrients:
  - Vitamins
  - Minerals (1-2.5%)
WHEAT
WHEAT PRODUCING COUNTRIES

(source: faostat.fao.org) Million tons (average 2005-2010)
WHEAT KERNEL

[Images of wheat kernels and a diagram showing the different parts of a wheat kernel, including bran, endosperm, and germ.]
WHEAT KERNEL

Crease

ENDOSPERM

Pigment Strand

BRAN

GERM

(80%)

(17%)

(3%)
MILLING: ONE STEP?
GOAL OF MILLING

- Bran
- Fine white flour
- Bran
- Semolina
FROM CEREAL TO FLOUR

- Milling:
  - Separation of bran/germ from endosperm
  - Size reduction of endosperm -> flour

- Processing steps involved
  - Reception and pre-cleaning
  - Cleaning
  - Conditioning
  - Milling
  - Sieving
  - Blending
CLEANING TECHNOLOGY

SIEVE SEPARATOR

OVERSIZE
GOOD
UNDERSIZE
AIR/LIGHT PRODUCT MIX

ASPIRATOR

Disk separator

MAGNET
CLEANING TECHNOLOGY

SCOURER

ENTOLETER
TEMPERING

- controlled addition of water (and heat)
- intensive mixing to ensure uniform distribution
- resting for a period of time (3-36 h)
  - optimal distribution in different parts of kernel
  - reduce hydration differences
- 25°C
  - Soft wheat: 15 – 16.5%
  - Hard wheat: 17 - 18%
TEMPEERING

- = adjustment of moisture content
  - not too dry
    - bran should become elastic to avoid splintering and contamination of flour
    - better separation of endosperm-bran
    - less power required to grind to flour
  - not too wet
    - endosperm too soft, no creation of sharp particles
    - no efficient sieving
TEMPERING

- Blending
  - Before
  - After

⇒ goal: to produce a standard quality wheat flour
⇒ eg. breadmaking quality
MILLING: BREAK ROLLS

- 4-5 breaks, corrugated rolls
  - first break opens kernel
  - subsequent breaks: scraping endosperm from the bran
  - gradually smaller but more corrugations
  - differential from 2.5 to 1
ROLLER MILLING
PLANSIFFTER
PLANSIFTER

FLOUR

To reduction rolls

To break rolls

To purifier
REDUCTION ROLLS

- Smooth rolls
- coarse reduction (scratching or sizing)
  - removing small pieces of bran and germ from endosperm
  - smaller particles endosperm
- fine reduction
  - grinding endosperm into flour
  - minimum in crushed germ and bran powder
  - optimum in damaged starch granules
PURIFIER

- Separating bran and endosperm particles of similar size
- Combinations of sieving and aspiration
MILLING SCHEME

Four main groups of machines are shown:

- Break and reduction rolls
- Furifiers
  - Coarse
  - Medium coarse
  - Fine sieves

The flour streams are not shown but each representation of a bolting silk implies that a flour stream originates there and is named after the rolls that feed the sifter in question.
MILLING SCHEME
MILLING: CONCLUSION

- Milling process
  - multi-stage process
  - size reduction, separation (sieving) and purification operations
  - different materials at different stages BUT no fraction completely pure

- Milling efficiency
  - flour extraction degree
  - pureness of the fractions
MILLING: FINAL STAGE

- Wheat flour: blending all flour streams

![Diagram of flour blending process]

Streams:
- Premier Feeder
- Flour In
- Mixing Conveyor
- Flour Out
- Packaging
EXTRACTION RATE

% Extraction

Whole Wheat Meal of Flour

Straight Grade Flour | Shorts and Bran

Patent Flour | Low Grade Flours

Source: principles of cereal science and technology, Hoseney
Table 1
Chemical composition (dry basis) of wheat flour in function of the extraction rate (Pederson et al., 1989)

<table>
<thead>
<tr>
<th></th>
<th>Extraction rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Starch + sugar (%)</td>
<td>69.9</td>
</tr>
<tr>
<td>Protein (n × 6.25) (%)</td>
<td>14.2</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>2.7</td>
</tr>
<tr>
<td>Dietary fiber (%)</td>
<td>12.1</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>1.8</td>
</tr>
<tr>
<td>Energy (kJ/g)</td>
<td>18.5</td>
</tr>
<tr>
<td>Phosphorus (mg/g)</td>
<td>3.8</td>
</tr>
<tr>
<td>Calcium (mg/g)</td>
<td>0.44</td>
</tr>
<tr>
<td>Zinc (ppm)</td>
<td>29</td>
</tr>
<tr>
<td>Copper (ppm)</td>
<td>4.0</td>
</tr>
<tr>
<td>Iron (ppm)</td>
<td>35</td>
</tr>
<tr>
<td>Thiamine (µg/g)</td>
<td>5.8</td>
</tr>
<tr>
<td>Riboflavin (µg/g)</td>
<td>0.95</td>
</tr>
<tr>
<td>Niacin (µg/g)</td>
<td>25.2</td>
</tr>
<tr>
<td>Pyridoxine (µg/g)</td>
<td>7.5</td>
</tr>
<tr>
<td>Biotin (µg/g)</td>
<td>116</td>
</tr>
<tr>
<td>Folic acid (µg/g)</td>
<td>0.57</td>
</tr>
</tbody>
</table>
MAIZE
CORN PRODUCING COUNTRIES

(source: faostat.fao.org) Million tons (average 2005-2010)
CORN/MAIZE

- Most produced grain
- Highest yielding cereal (world average)
  - Maize: 4.3 tonnes/hectare
  - Paddy rice: 3.8 tonnes/hectare
  - Wheat: 2.7 tonnes/hectare
- Animal feed
- Human food: tortillas, porridge
- Starch production: wet milling

http://www.baobab.net
MAIZE GRAIN

endosperm
- floury endosperm
- horny endosperm
- endosperm cells with starch granules
- aleurone cell layer

bran
- seed coat (testa)
- tube cells
- cross cells
- mesocarp
- epidermis

germ (embryo)
- plumule
- scutellum
- radicle

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MAIZE TYPES

TYPES
Dent
Soft
Waxy
Popcorn
Sweet
White
MAIZE PROCESSING: TANZANIA
MAIZE CLEANING AND TEMPERING
HAMMER MILL: SMALL SCALE MILLING
HAMMER MILL: FORTIFICATION
ROLLING MILL: LARGE SCALE OPERATIONS

- Gradual size reduction
- Sieving + roller milling
- Flour streams are blended in mixing conveyor
MAIZE MEAL COMPOSITION

- Maize variety / type of milling / extraction rate

Typical Extraction Rates for Maize meal

<table>
<thead>
<tr>
<th>Mill size</th>
<th>Maize meal Extraction Rate %</th>
<th>Kernel Components for conversion to maize flour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>70 - 75</td>
<td>Endosperm with some pericarp and germ</td>
</tr>
<tr>
<td>Medium</td>
<td>65 - 70</td>
<td>Endosperm, pericarp and germ</td>
</tr>
<tr>
<td>Small</td>
<td>60 - 65</td>
<td>Endosperm little or no pericarp and germ</td>
</tr>
</tbody>
</table>

NOTE:
Pericarp and germ components can influence the taste of the cooked porridge.
Bitterness is one of the characteristic tastes from the pericarp and germ.
The purer the endosperm used to mill into flour the lower the bitterness taste.
# MAIZE MEAL QUALITY

## Composition of Maize Product

<table>
<thead>
<tr>
<th>Class of Maize Product</th>
<th>Fat Content by Mass (%)</th>
<th>Fiber Content by Mass (%)</th>
<th>Fineness by Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td>1. Super Maize Meal</td>
<td>-</td>
<td>Less than 2.0</td>
<td>-</td>
</tr>
<tr>
<td>2. Special Maize Meal</td>
<td>2.0</td>
<td>Less than 3.0</td>
<td>-</td>
</tr>
<tr>
<td>3. Sifted Maize Meal</td>
<td>3.0</td>
<td>Less than 4.0</td>
<td>-</td>
</tr>
<tr>
<td>4. Unsifted Maize Meal</td>
<td>3.5</td>
<td>Less than 4.5</td>
<td>More than 1.2</td>
</tr>
<tr>
<td>5. Samp</td>
<td>-</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>6. Maize Rice</td>
<td>-</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>7. Maize Grit</td>
<td>-</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>8. Maize Flour</td>
<td>-</td>
<td>Less than 2.0</td>
<td>-</td>
</tr>
<tr>
<td>9. No. 1 Straightrun Maize Meal</td>
<td>3.7</td>
<td>-</td>
<td>1.8</td>
</tr>
<tr>
<td>10. No. 2 Straightrun Maize Meal</td>
<td>3.7</td>
<td>-</td>
<td>More</td>
</tr>
</tbody>
</table>
Different wheat and maize types
Processing of wheat and maize is different
Milling in large scale operations is multistep process which includes consecutive milling, sieving and purifying
Extraction rate is important and also determines flour or meal quality
Filip Van Bockstaele
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