UNIVERSITEIT GENT

Milling technology for cereals

QA/QC on flour fortification, Kampala, 24-05-2016

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FACULTY OF BIOSCIENCE ENGINEERING

LABORATORY OF CEREAL TECHNOLOGY

Cereals

Cereal grains

- *Ceres*
- What are cereals?
  - Grass family (*Gramineae*)
  - One seeded fruits
    - **Caryopsis** = kernel = grain
      - Germ
      - Endosperm
      - Bran: seed coat and fruit coat
    - Developes in glume (chaff, husk)
  - Easy to grow, high yield, stable, storage

Cereal grains

Regnum	*Eucarya*
Subregnum	*Chlorobionta*
Phylum	*Streptophyta*
Subphylum	*Spermatophytina* (seed plants)
Classis	*Magnoliopsida* (flowering plants)
Subclassis	*Lilidae* (monocots)
Ordo	*Poales* **cereals**
Familia	*Poaceae* (*Gramineae*)

pseudo-cereals

Ordo *Caryophyllales/Polygonales*
- Familia *Amaranthaceae*: *Amaranthus paniculatus* (amaranth)
- Familia *Chenopodiaceae*: *Chenopodium quinoa* (quinoa)
- Familia *Polygonaceae*: *Fagopyrum esculentum* (buckwheat)

Ordo *Malpighiales*
- Familia *Euphorbiaceae*: *Manihot esculentum* (cassava)

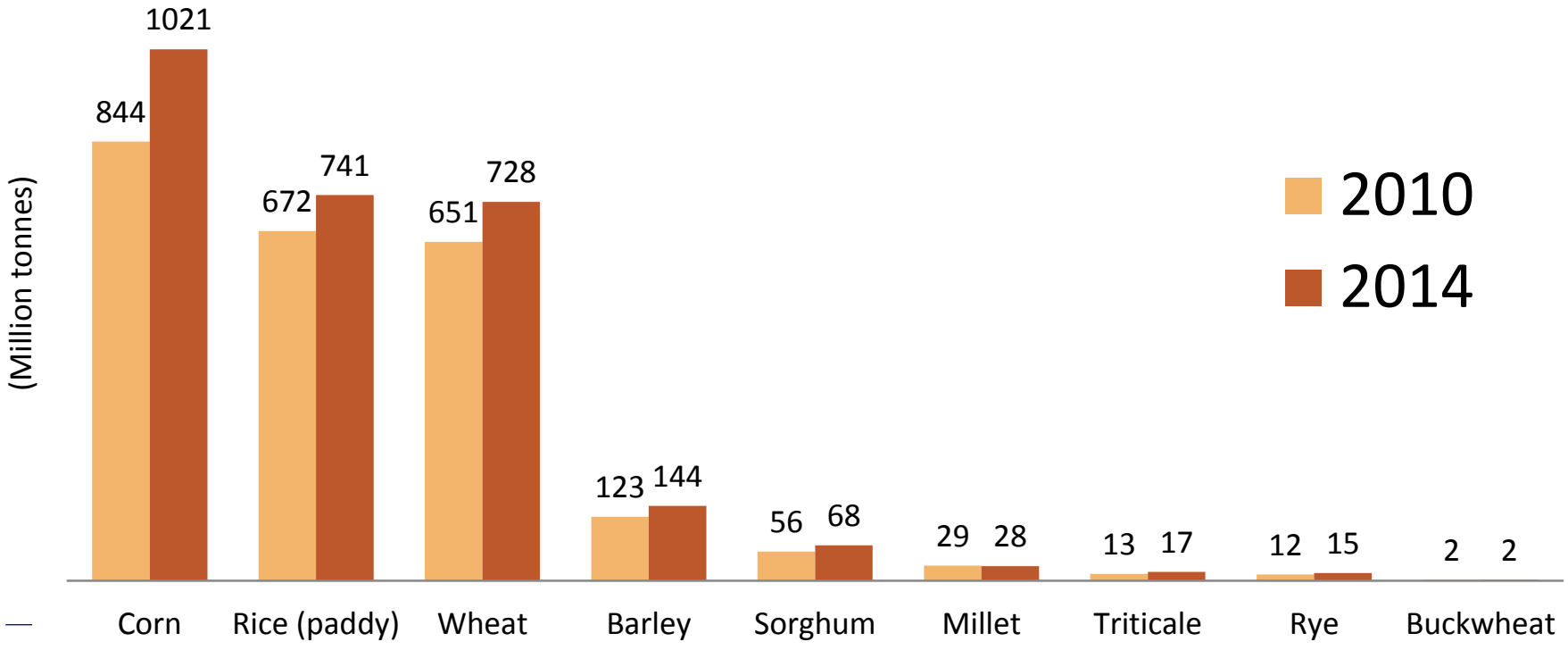
Rosidae (dicots)

Subfamilia	*Poideae*				*Oryzoideae*	*Panicoideae*					*Chlorodoideae*	
Genus	*Triticum*	*Secale*	*Hordeum*	*Avena*	*Oryza*	*Zea*	*Sorghum*	*Pennisetum*	*Setaria*	*Panicum*	*Eragrostis*	*Eleusine*
Species	*durum* *turgidum* *aestivum* *spelta*	*cereale*	*vulgare*	*sativa*	*sativa*	*mays*	*bicolor*	*glaucum*	*italica*	*miliaceum*	*tef*	*coracana*
Aegilops squarossa												
	wheat	rye	barley	oat	rice	maize	sorghum	pearl millet	Italic millet	true millet	teff	finger millet

T. turgidocereale; **triticale**

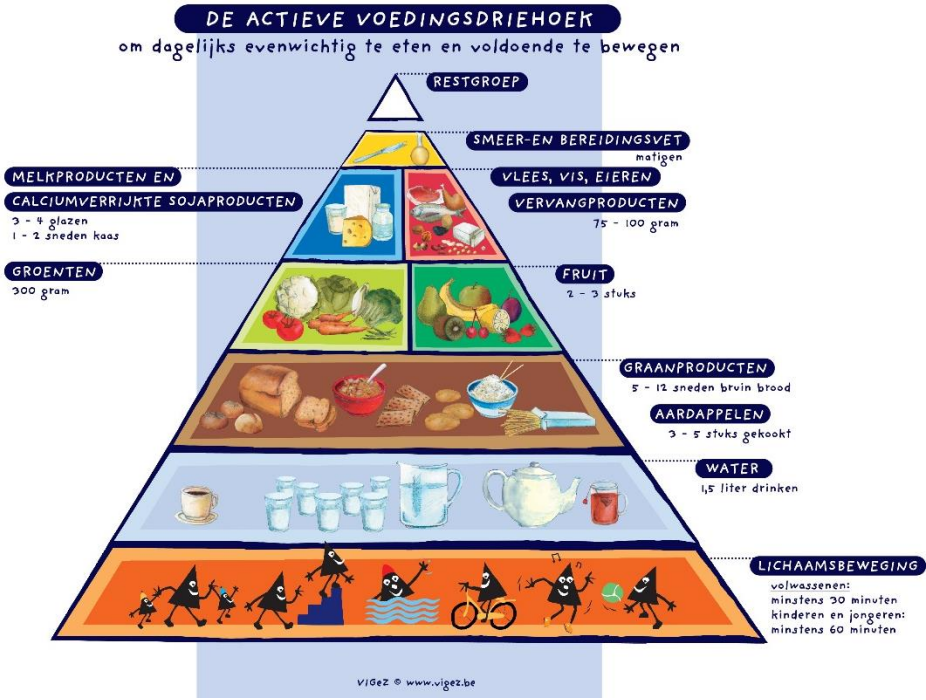
Cereals in the world

- Annual production of major cereals in 2010/2014 (source: 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%)



Dewettinck, K., Van Bockstaele F., Kühne, B., Van de Walle, D., Courtens, T. and Gellynck, X. (2008). Nutritional value of bread: influence of processing, food interaction and consumer perception. Jounal of Cereal Science, 48, 243-257.

Wheat

Wheat grain

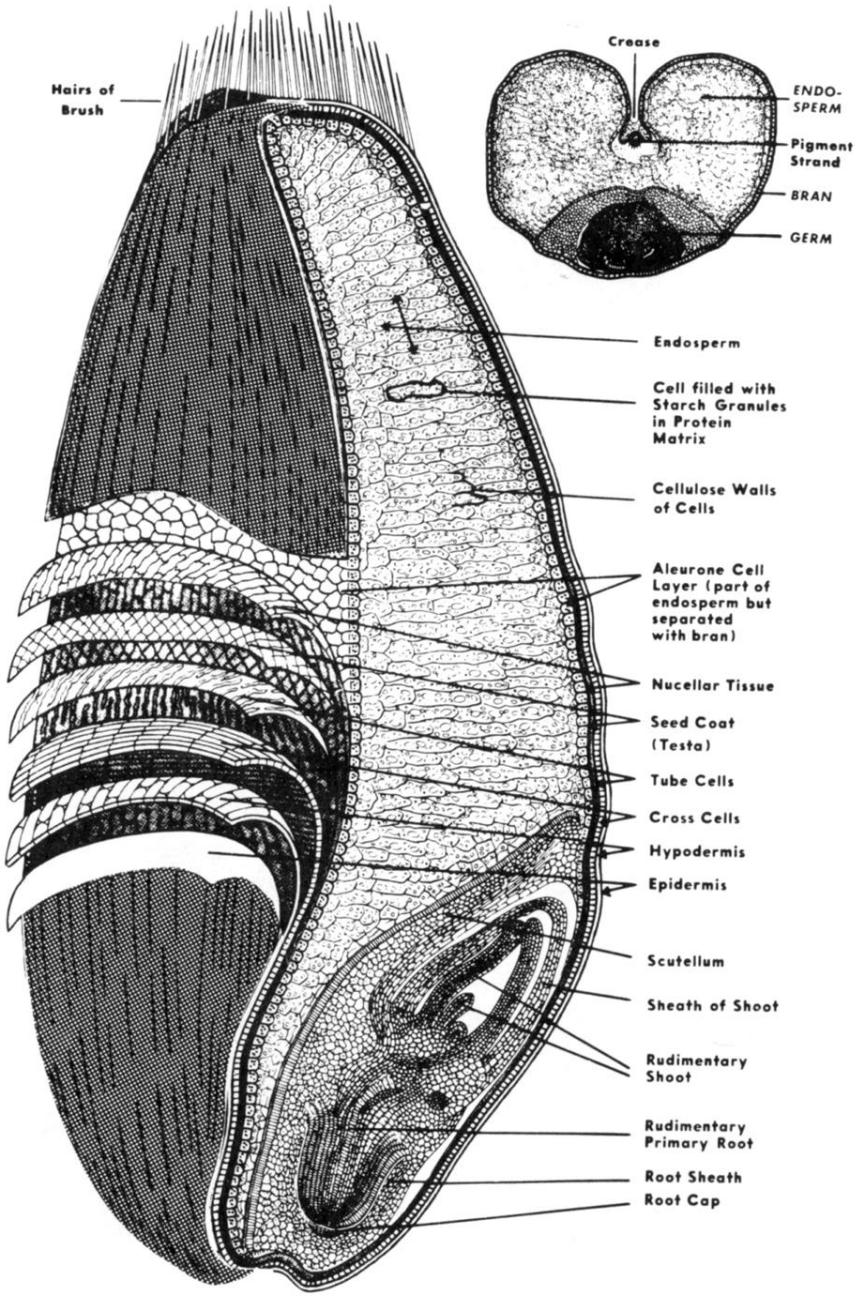


Fig. 2. Longitudinal and cross sections of a wheat kernel.

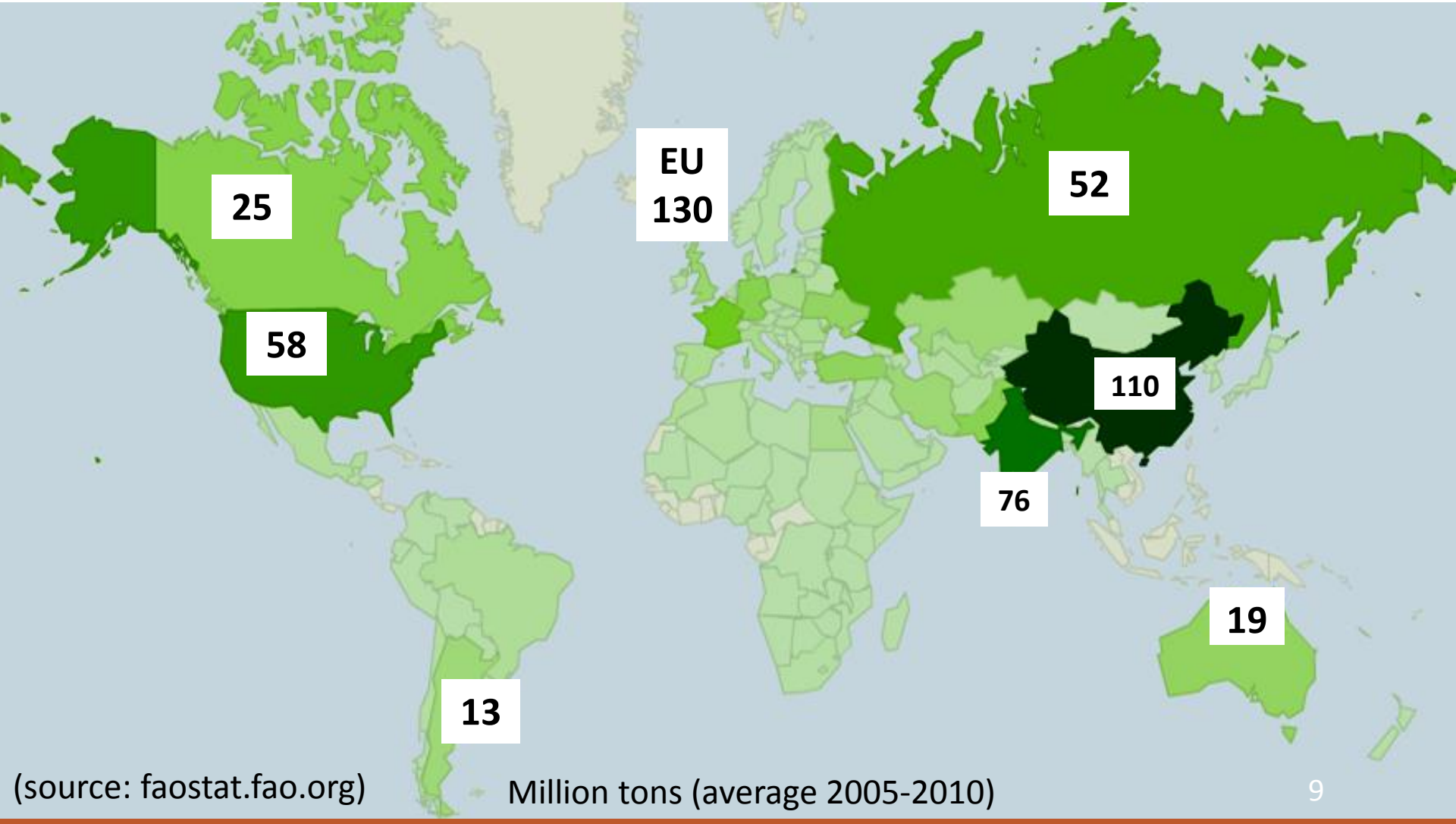
ENDOSPERM (80%)

BRAN (17%)

Incl. aleuronlayer

GERM (3%)

Wheat producing countries



(source: faostat.fao.org)

Million tons (average 2005-2010)

Wheat

- Unique
  -> wheat gluten proteins
  -> breadmaking quality

Wheat classification

- Wheat class system depends on country
- Wheat type
  - *Triticum aestivum* (>90%)
  - *Triticum durum* (±5%)
- Criteria (USA)
  - Kernel texture: hard ↔ soft
  - Bran color: red ↔ white
  - Growth habit: spring ↔ winter

WHEAT CLASSES

Hard Red Spring wheat

Durum wheat

Hard Red Winter wheat

Soft Red Winter wheat

Soft White Winter wheat

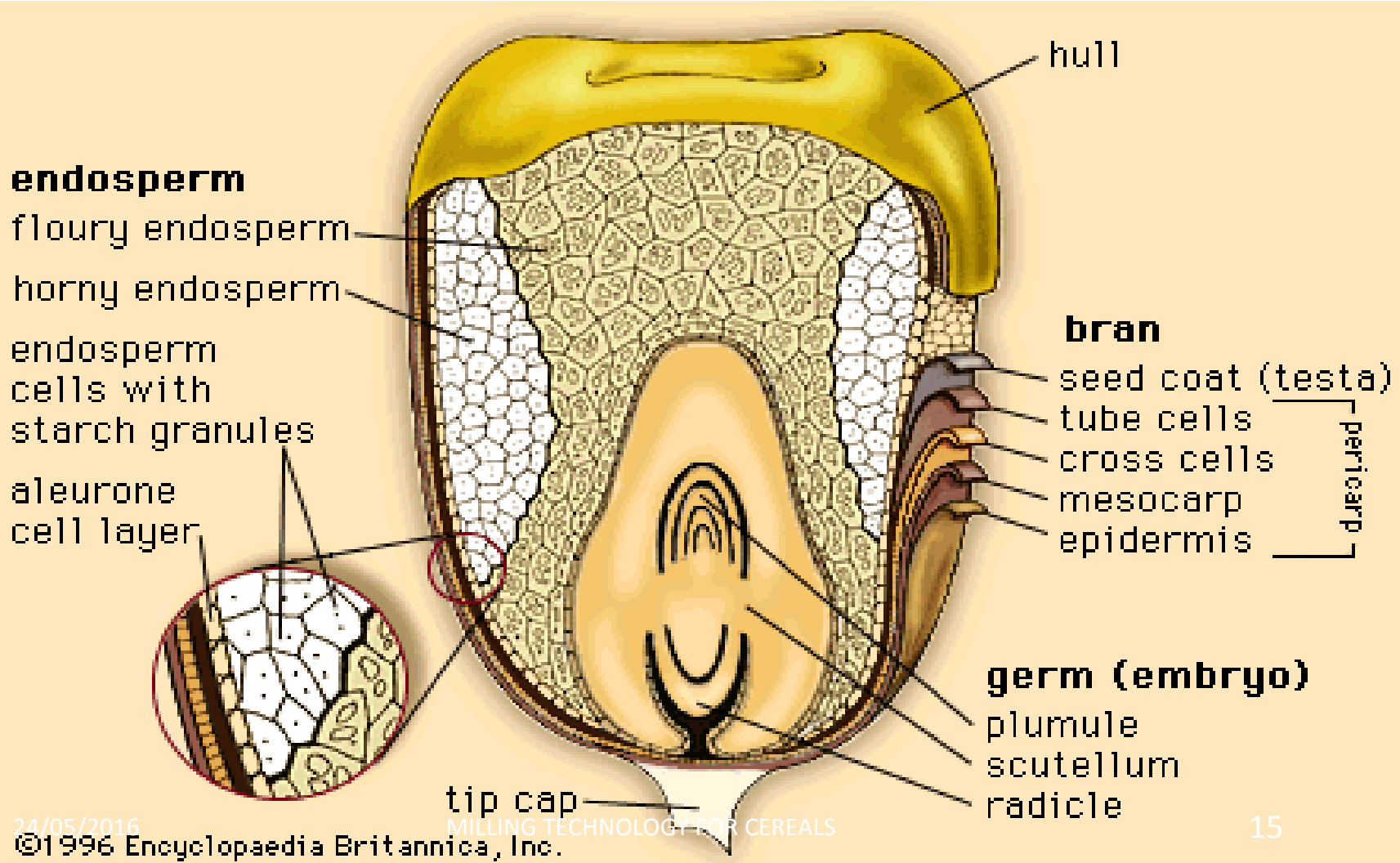
Mixed wheat

Maize

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

Maize grain


hull
endosperm
floury endosperm
horny endosperm
endosperm cells with starch granules
aleurone cell layer
bran
seed coat (testa)
tube cells
cross cells
mesocarp
epidermis
pericarp
germ (embryo)
plumule
scutellum
radicle
tip cap
©1996 Encyclopaedia Britannica, Inc.

Maize

TYPES

Dent

Soft

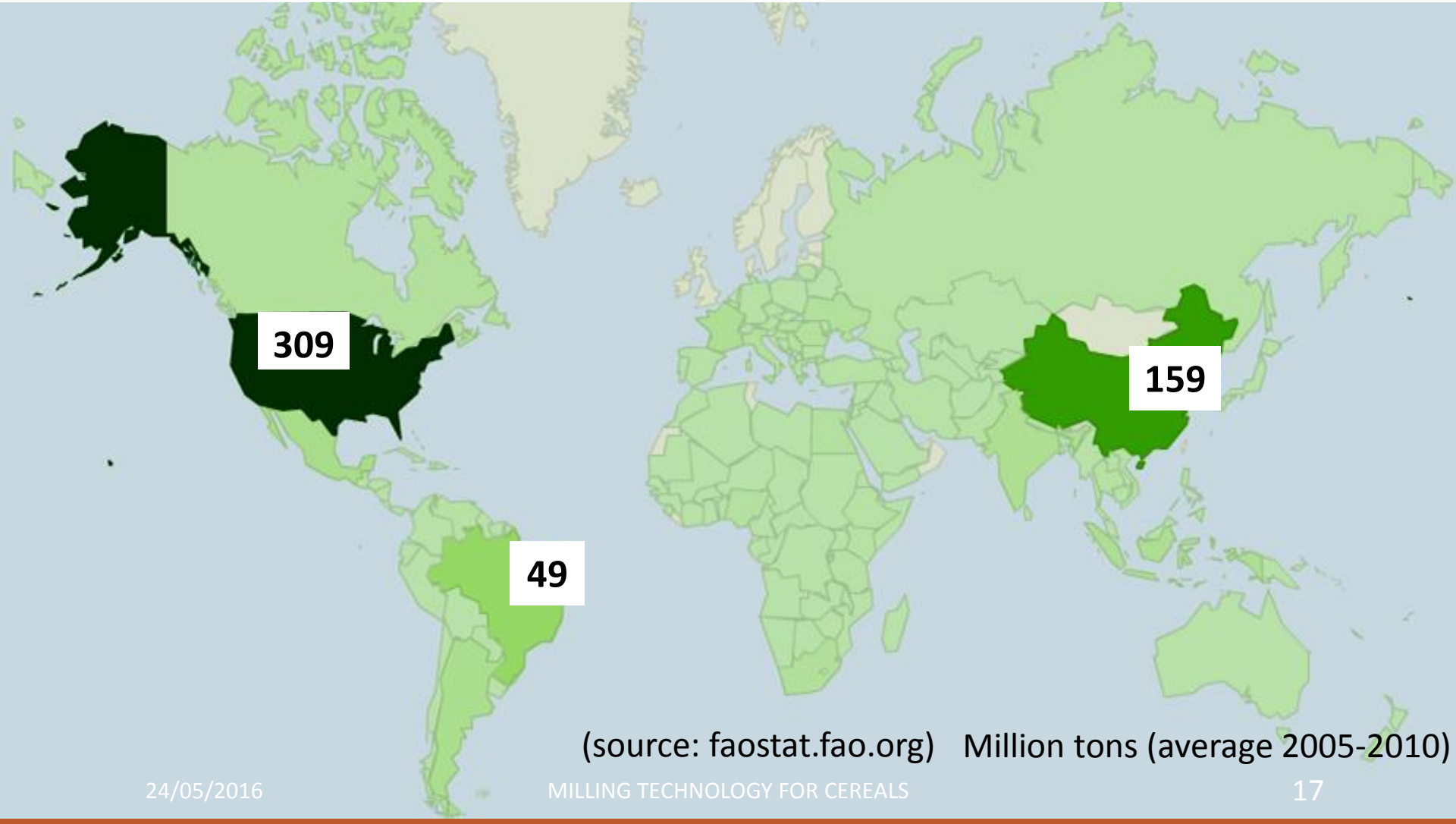
Waxy

Popcorn

Sweet

White

Corn producing countries



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

Cereal milling

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

Reception

- Reception
  - intake of cereals
  - quality control!: IN -> OUT
  - different factors

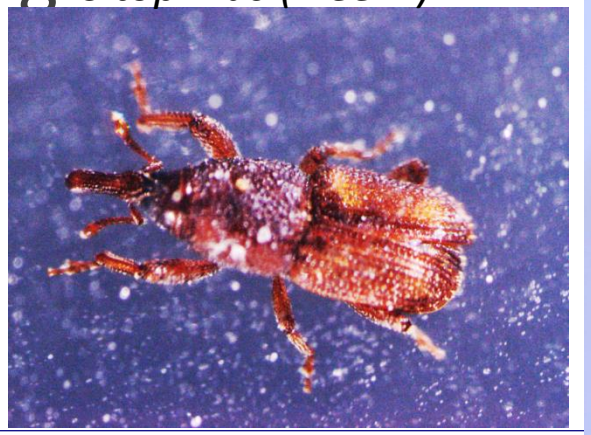
  - pre-cleaning
    - magnet
    - sieve cleaner
    - aspiration

Factors affecting milling yield, end use quality

- hectoliter weight
- Impurities
- Immature kernels
- Preharvest sprouting
- Insect damage

Courtesy: Marieke Dhooge

Sitophilus (weevil)



Factors affecting food safety: moulds

FUSARIUM SPP.

Mycotoxins!

Courtesy: Kris Audenaert

ERGOT

- *Claviceps purpurea*
- Toxic alkaloids
- Difficult to separate
- 0.05% limit

Courtesy: Ingrid De Leyn

Wheat grain quality control

- Fast analysis before grain intake:
  - Moisture content
  - Protein content
  - Hectoliter weight
  - %Impurities
  - Amylase activity -> Hagberg falling number
  - Gluten quality -> sedimentation value of Zeleny

Storage

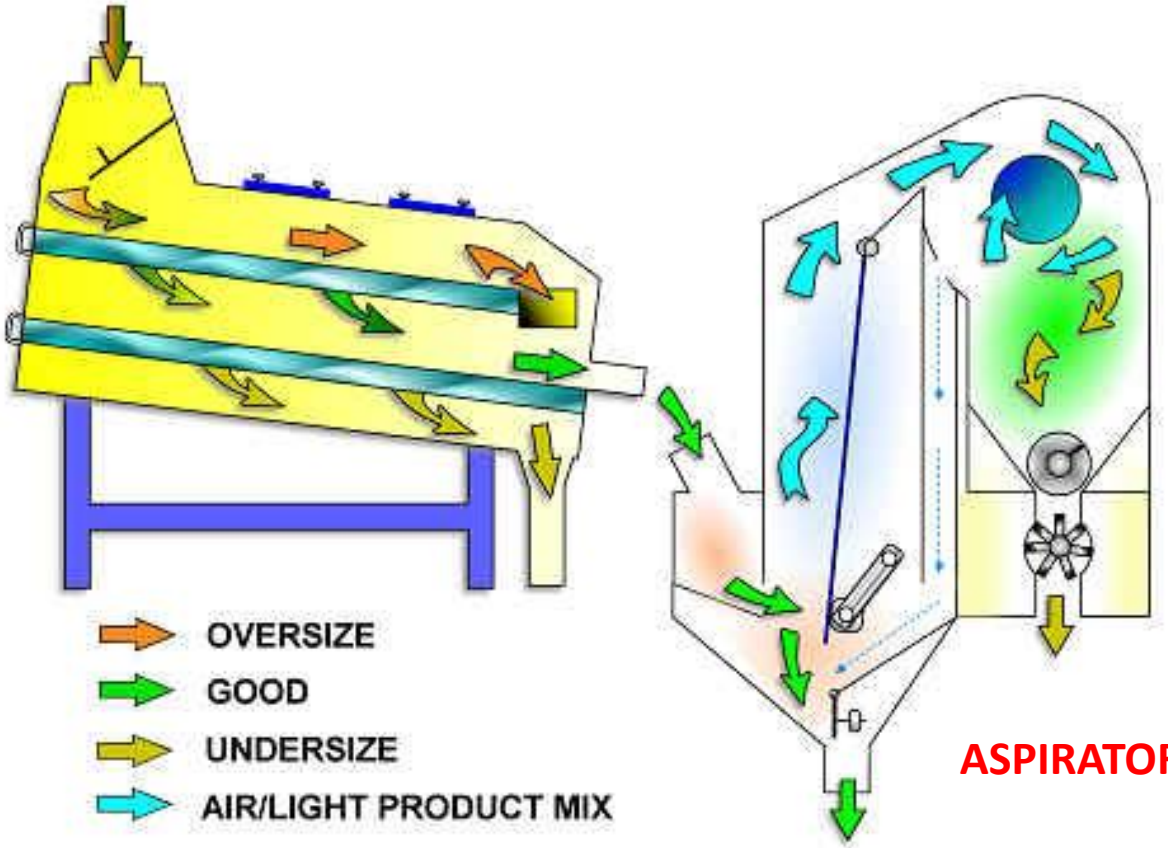
- Storage
  - possible: low moisture content
  - BUT living substance which can decay
- Control
  - temperature
  - grain condition
  - oxygen supply
  - moisture content grain
    - safe value ~ cereal (13-15%)
    - drying if necessary
  - pest and mould control

Blending and cleaning

- Blending
  - wheat mix of uniform quality
  - directly in storage bin
  - just before milling process (other tempering conditions)

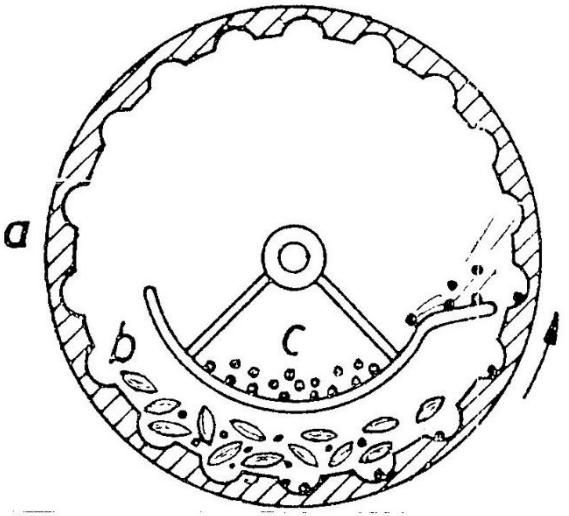
- Cleaning
  - remove impurities
    - undesired seeds, infested kernels, shrunken and broken kernels, other foreign material
  - prevent contamination of mill products + damage of equipment
  - separation based on differences in size, shape, specific gravity, behaviour in air currents, magnetic properties

Cleaning



SIEVE SEPARATOR

ASPIRATOR



DISC SEPARATOR

SCOURER

MAGNET

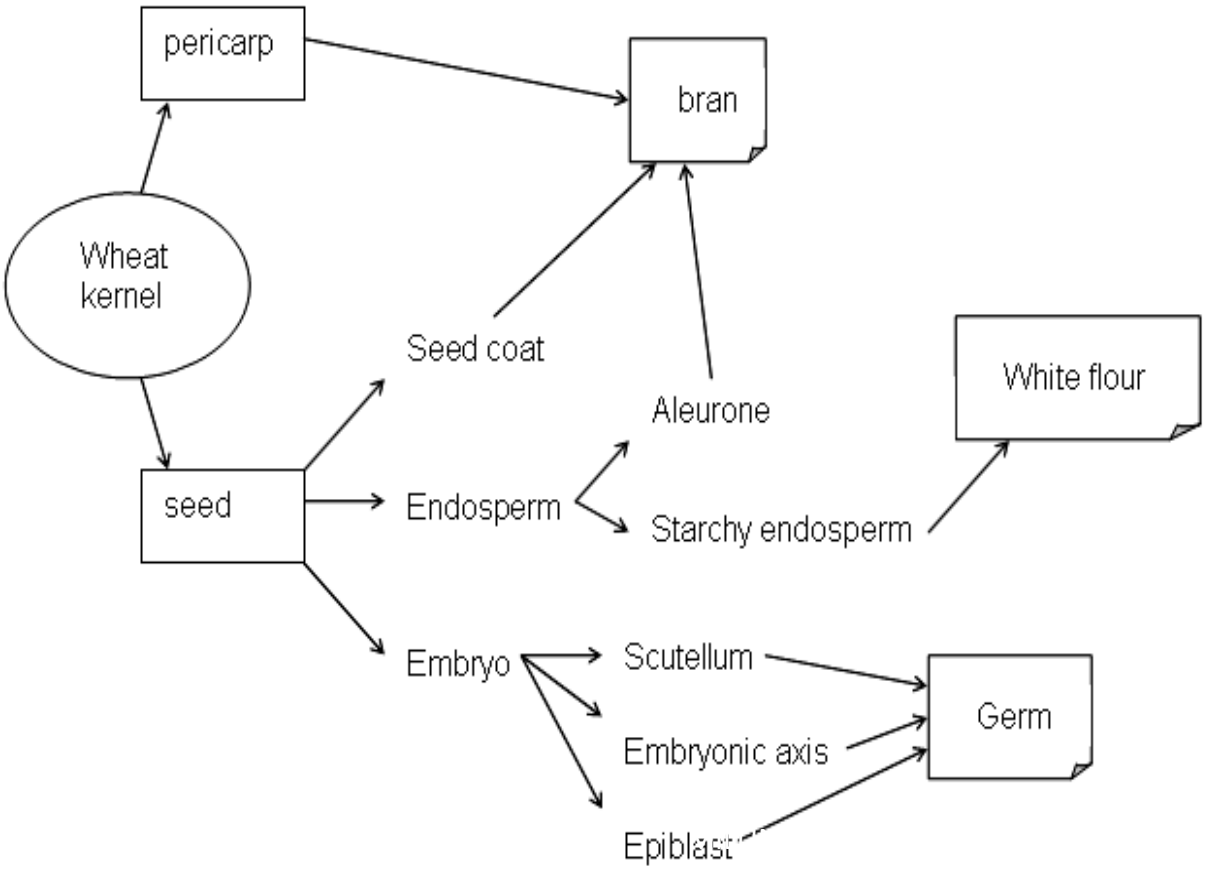
Conditioning

- Conditioning = **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

Conditioning

- 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, 15-20% moisture content
    - Soft wheat: 15 – 16.5%
    - Hard wheat: 17 - 18%

Milling: goals



- remove bran and germ
- flour with specific particle size distribution
- extract as much white flour as possible

Milling

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

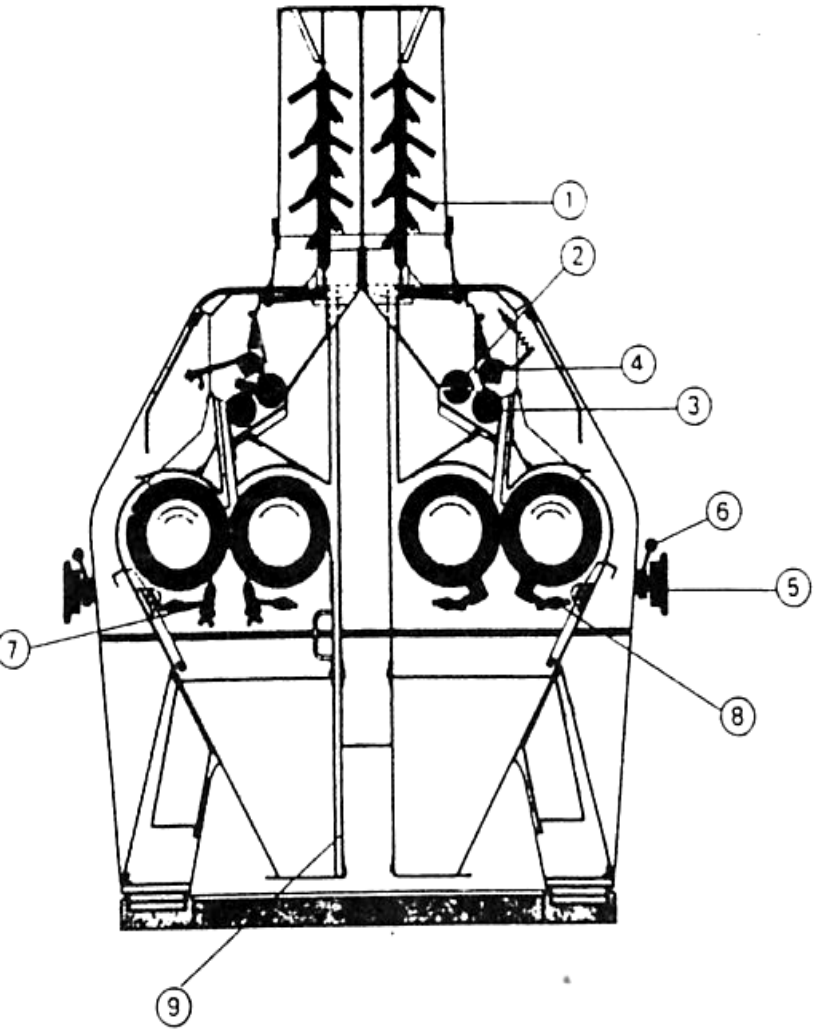
- Milling efficiency
  - flour extraction degree
  - pureness of the fractions

Milling process

- Succession of 3 systems:
  - breaking
    - breaks up grain in large pieces
    - removing endosperm from bran
    - as little flour and bran powder as possible
  - coarse reduction (scratching or sizing)
    - removing small pieces of bran and embryo from endosperm
    - smaller particles endosperm
  - fine reduction
    - grinding endosperm into flour
    - minimum in crushed germ and bran powder
    - **optimum** in damaged starch granules

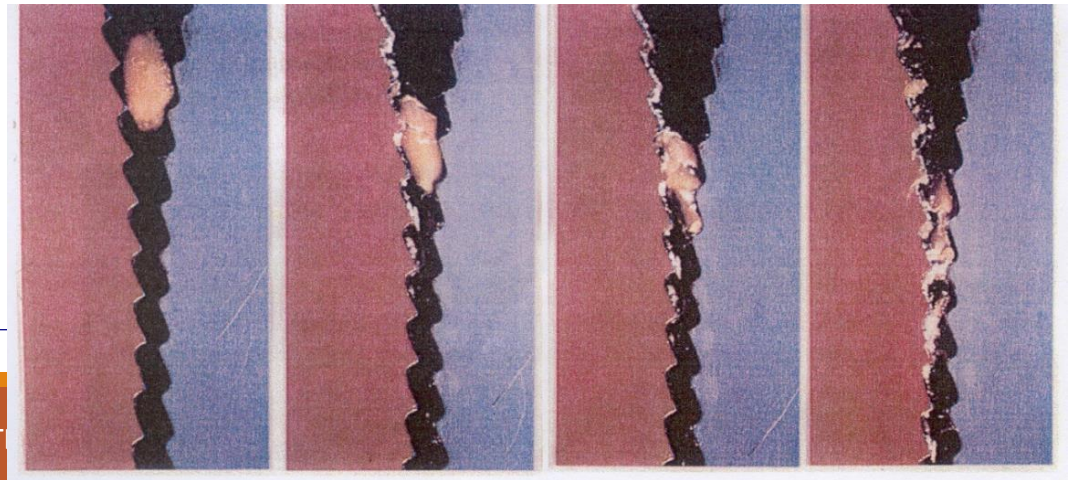
Sieving in between steps

Roller milling



Roller milling: break system

- 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

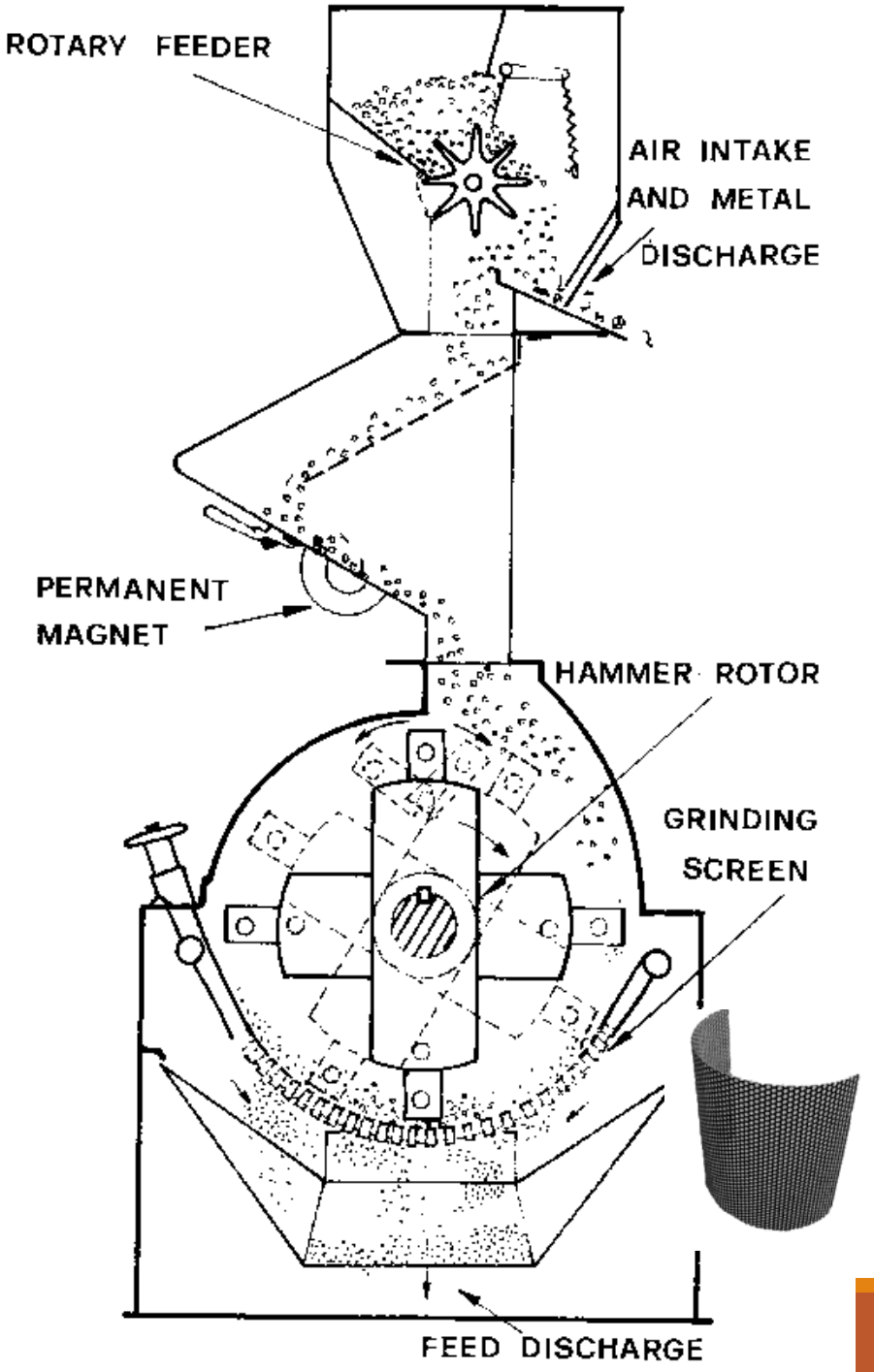


Roller milling: reduction system

- Gradual decrease of particle size into flour
- Roller mill with **smooth rolls**,
  - differential 1.25 to 1
  - high shear pressure, lower shear forces
- Coarse reduction: 3-5 stages
  - removing small pieces of bran and embryo from endosperm
  - Smaller particles endosperm
  - no severe grinding: no bran in flour
- Fine reduction: 6-10 stages
  - grinding endosperm into flour
  - minimum in crushed germ and bran powder
  - **Optimum** in damaged starch granules
- Material to purifiers, final reduction, flour

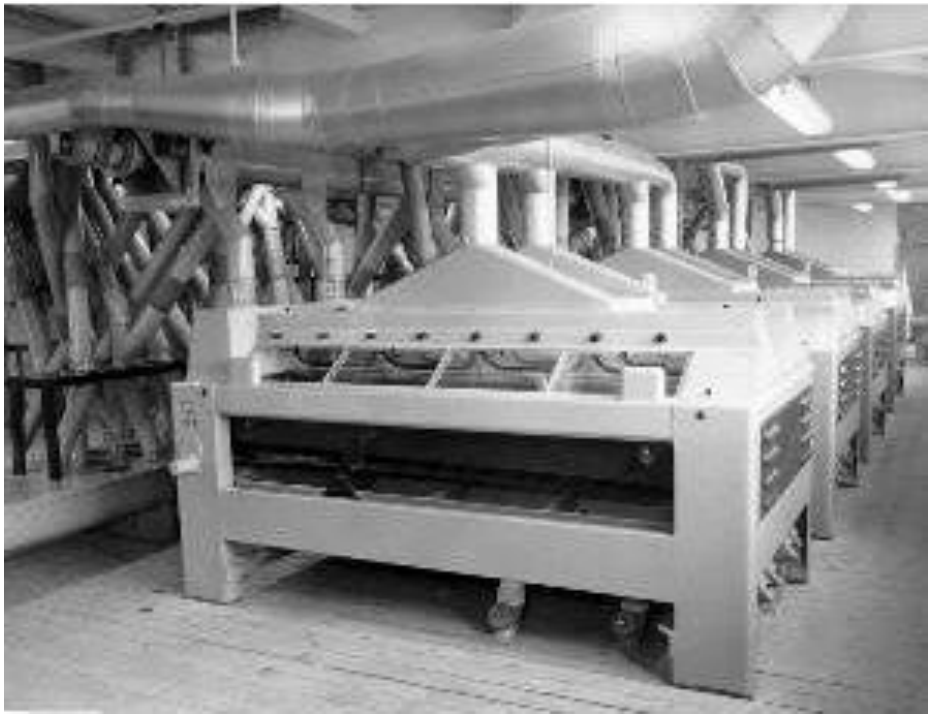
Hammer mill

- impact milling
- screen determines the particle size
- requires dehulling when applied for ‘white’ flour/meal



Sieving

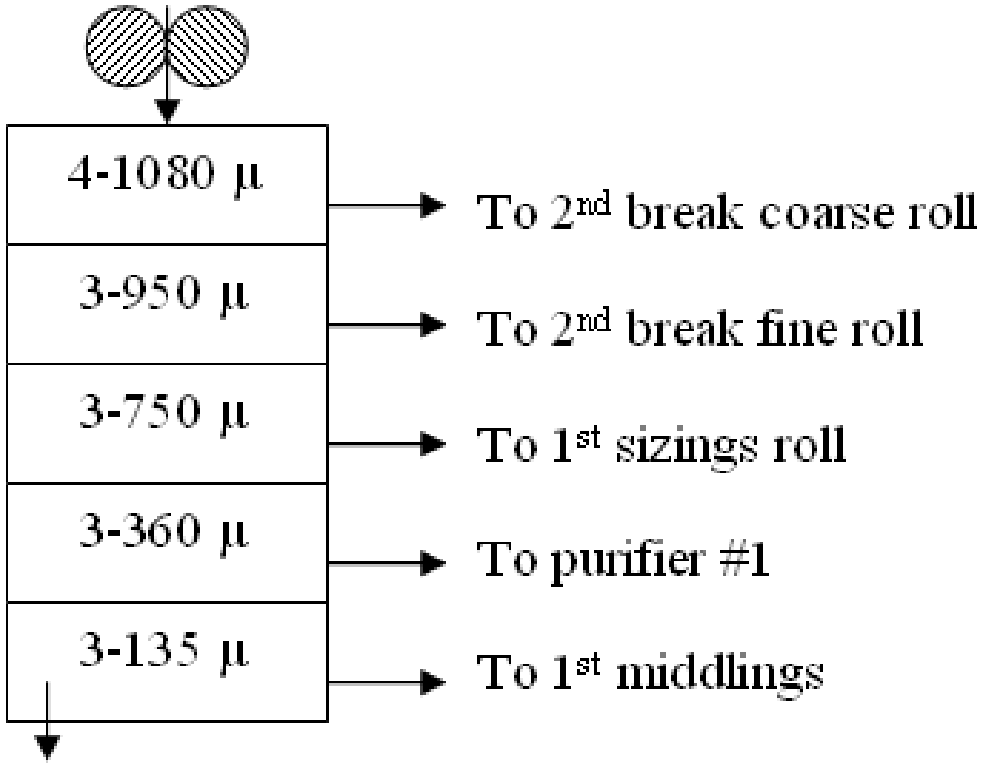
Plansifter



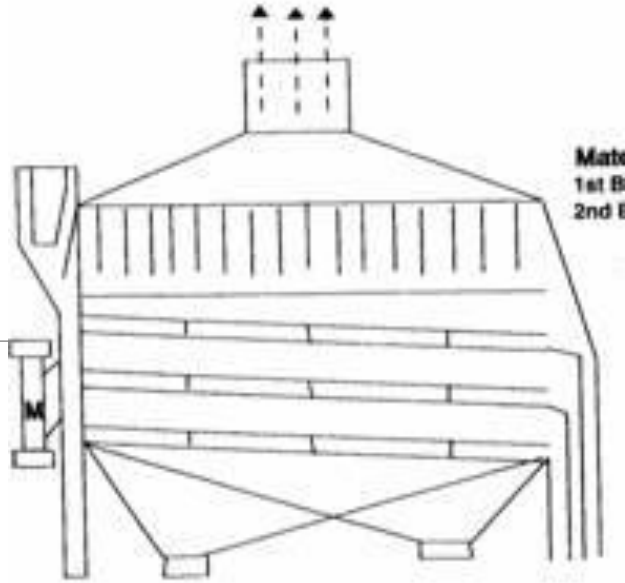
Purifier

Sieving: plansifter

- Sieving stage follows each set of rolls
  - different mill fractions
  - directed to:
    - Next break rolls
    - Reduction rolls
    - Purifier
    - Finished product

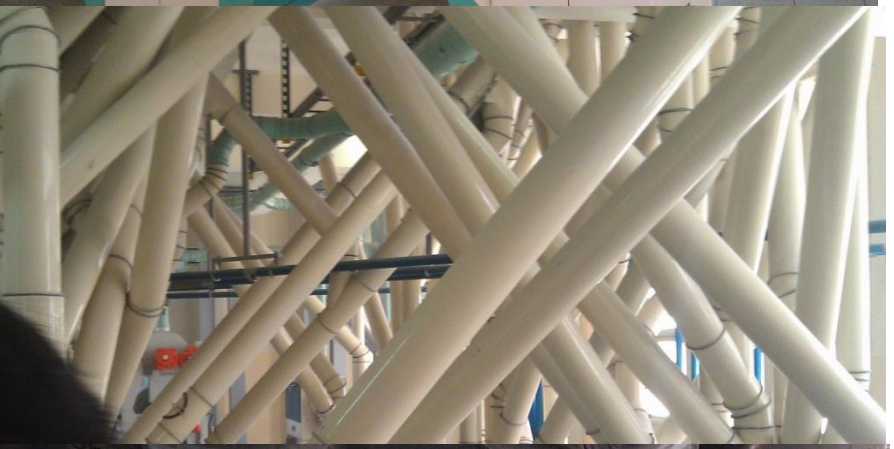


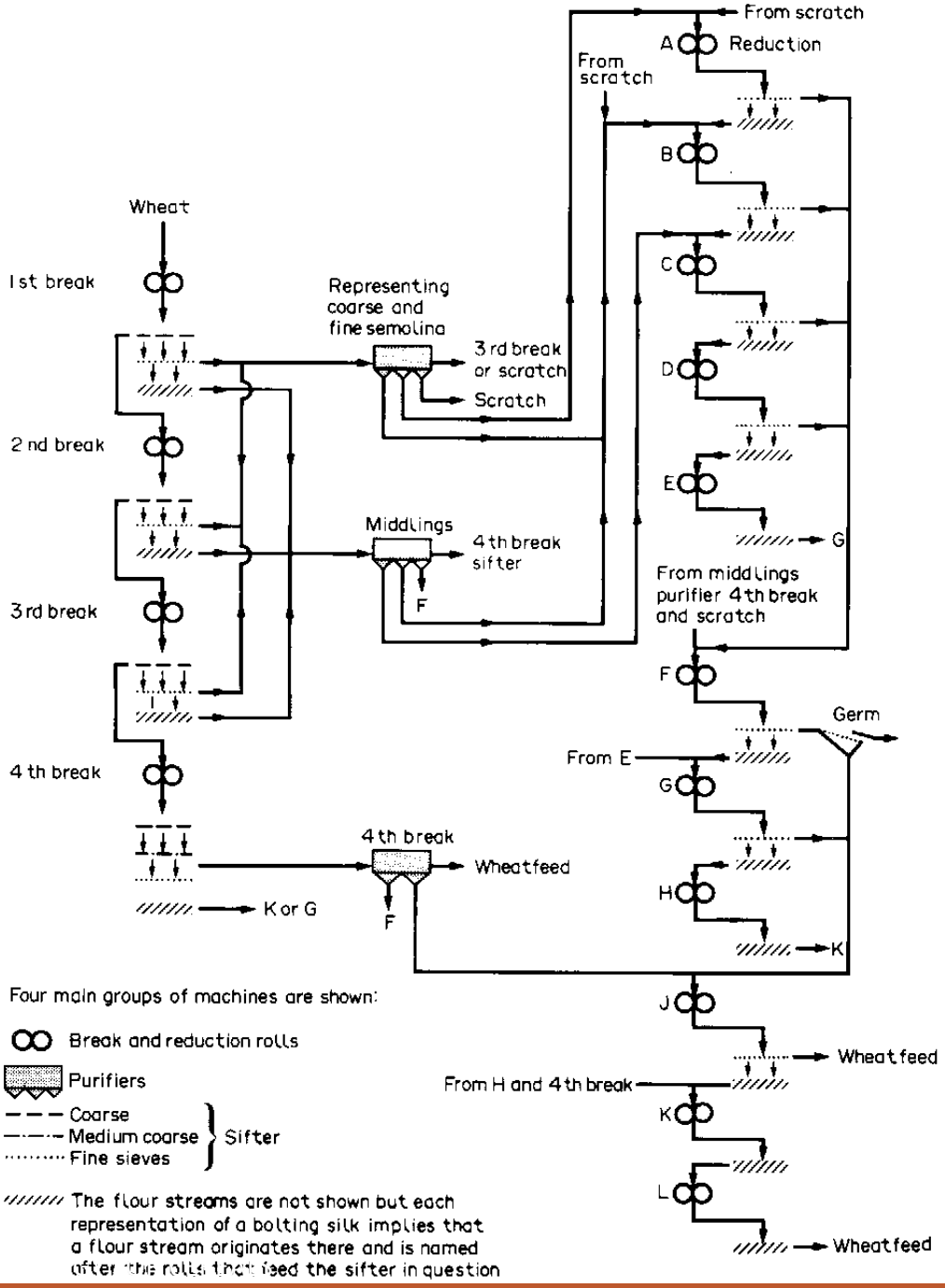
Sieving



- Purifiers

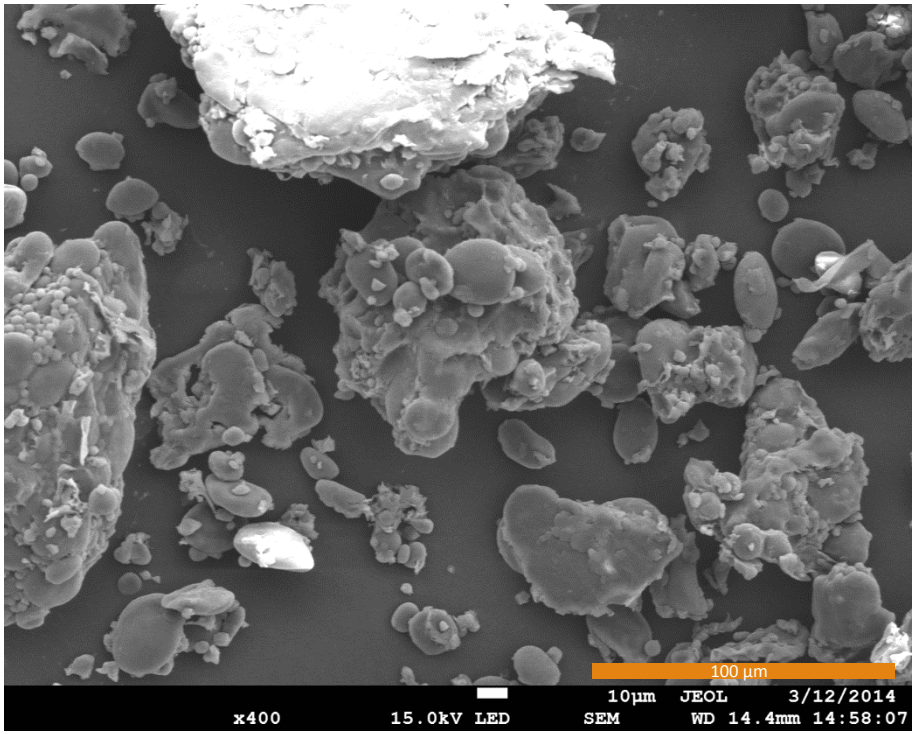
- separation of pure endosperm and endosperm with different amounts of bran
- **vibrating motion** of sieves: heavier endosperm close to sieve, brannier material on top
- **air currents** fluidise and stratify according to size, specific gravity and shape



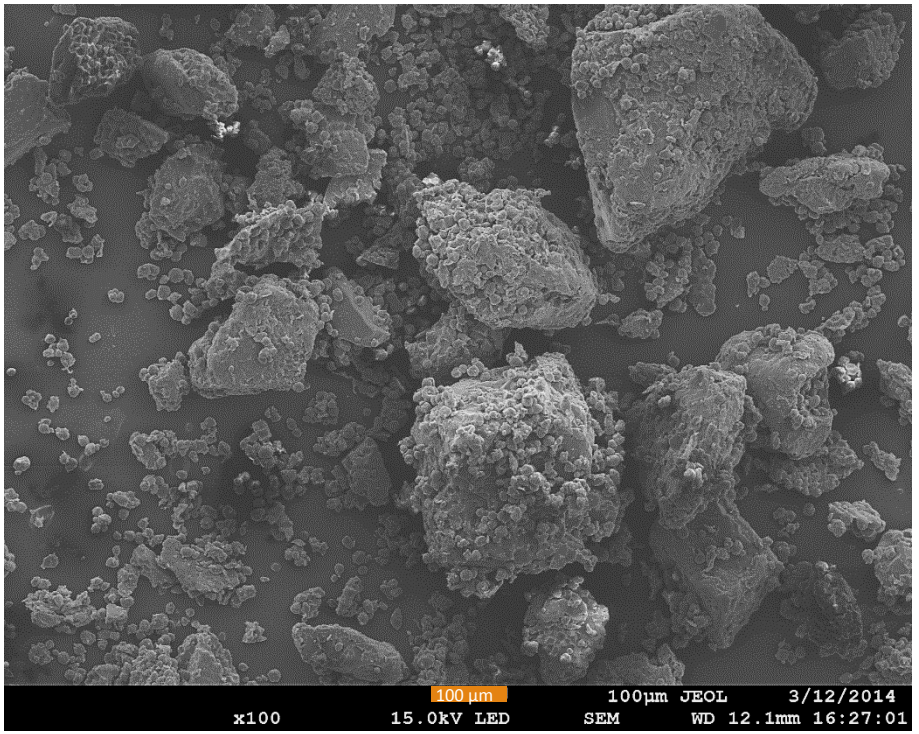

From scratch
A
Reduction
From scratch
B
C
D
E
G
Wheat
1st break
Representing coarse and fine semolina
3rd break or scratch
Scratch
2nd break
Middlings
4th break sifter
F
From middlings purifier 4th break and scratch
3rd break
F
Germ
From E
4th break
G
4th break
Wheatfeed
H
K or G
F
K
J
Wheatfeed
From H and 4th break
K
L
Wheatfeed
Four main groups of machines are shown:
Break and reduction rolls
Purifiers
Coarse
Medium coarse
Fine sieves
Sifter
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: end products

Wheat flour

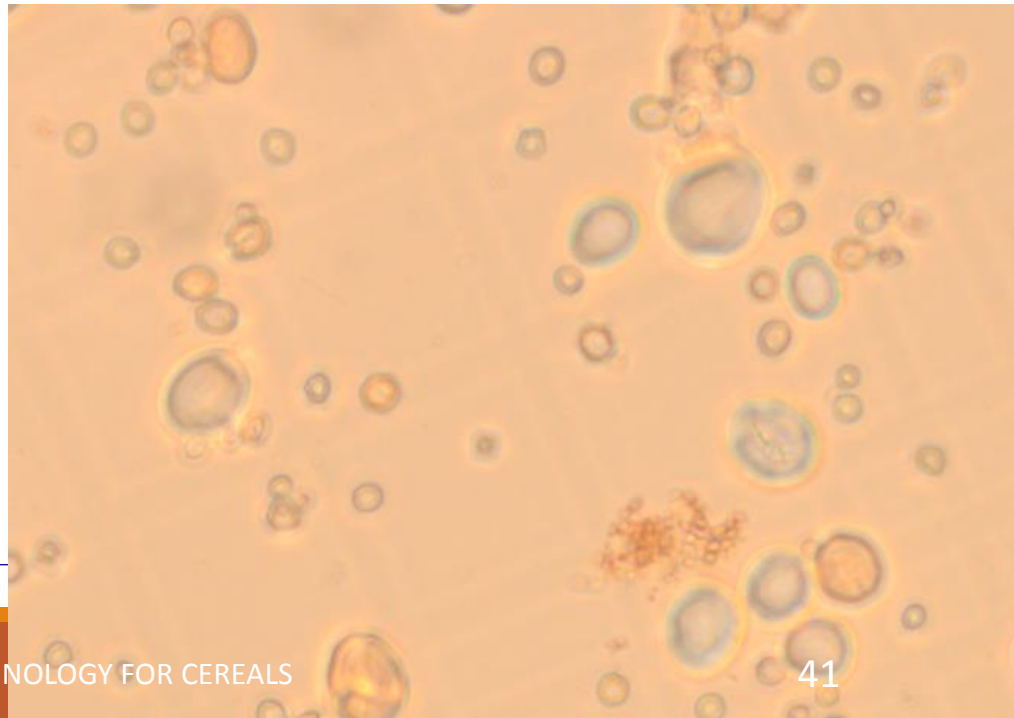


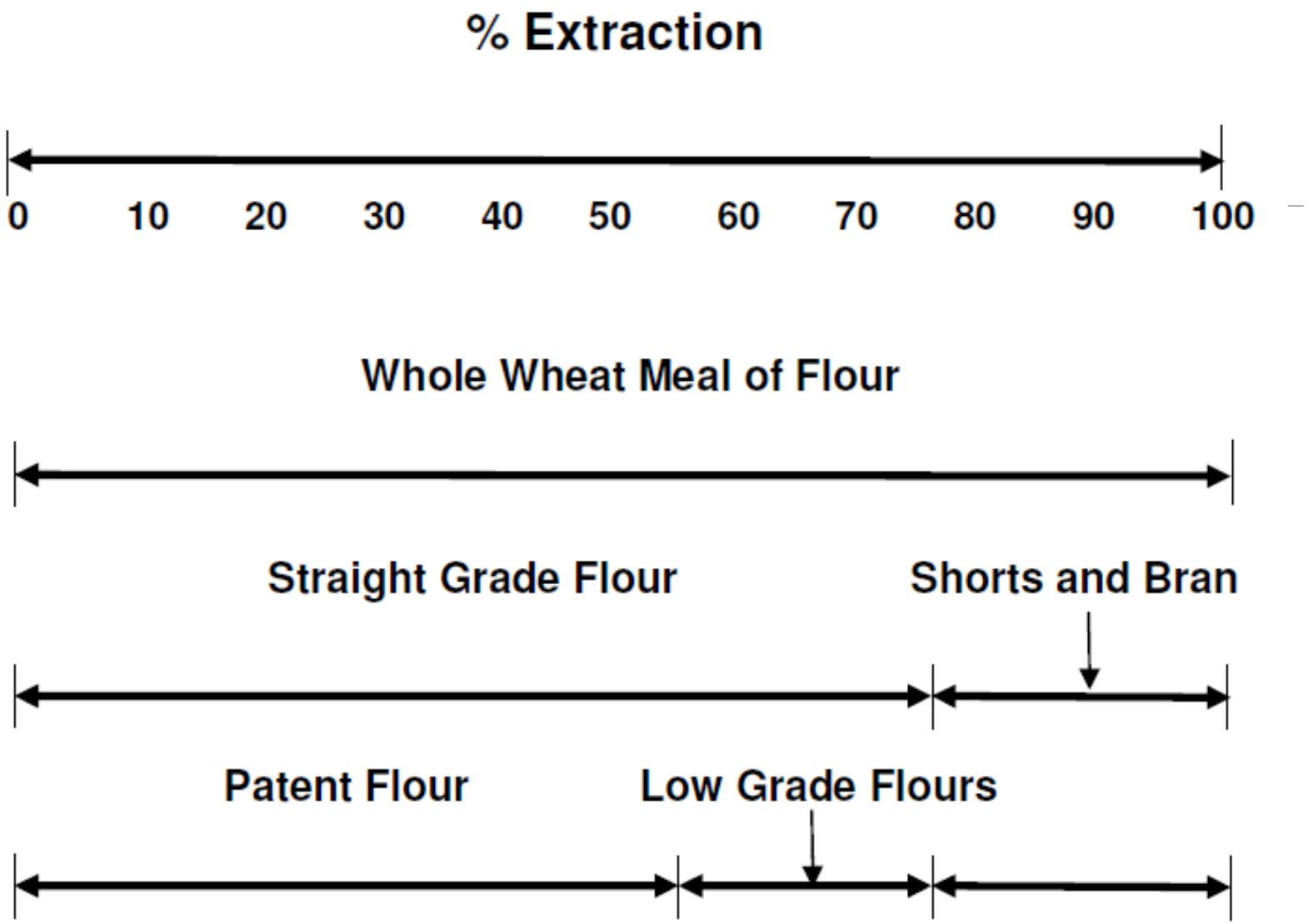
Maize meal



Milling and flour/meal quality

- Particle size
- Bran content -> ash content
- Color
- Starch damage





Source: principles of cereal science and technology, Hoseney

Composition of Maize Product

Class of Maize Product	Fat Content by Mass (%)		Fiber Content by Mass (%)		Fineness by Mass
	Minimum	Maximum	Minimum	Maximum	
1. Super Maize Meal	-	Less than 2.0	-	0.8	At least 90% shall pass through a 1.4mm sieve, and less than 90% shall pass through a 300micrometer sieve.
2. Special Maize Meal	2.0	Less than 3.0	-	1.2	At least 90% shall pass through a 1.4mm sieve.
3. Sifted Maize Meal	3.0	Less than 4.0	-	1.2	At least 90% shall pass through a 1.4mm sieve.
4. Unsifted Maize Meal	3.5	Less than 4.5	More than 1.2	2.5	At least 90% shall pass through a 1.4mm sieve
5. Samp	-	1.5	-	0.8	Not more than 5% shall be whole grain and not more than 5% shall pass through a 2.36mm sieve
6. Maize Rice	-	1.5	-	0.8	At least 90% shall pass through a 4.0mm sieve, and not more than 5% shall pass through a 1.18mm sieve
7. Maize Grit	-	1.5	-	0.8	At least 90% shall pass through a 2.0mm sieve, and not more than 5% shall pass through a 850micrometer sieve
8. Maize Flour	-	Less than 2.0	-	0.8	At least 90% shall pass through a 300micrometer sieve
9. No. 1 Straightrun Maize Meal	3.7	-	1.8	2.5	At least 90% shall pass through a 2.36mm sieve
10. No. 2 Straightrun	3.7	-	More	6.5	At least 90% shall pass through a

Courtesy: Philip Randall

Table 1
Chemical composition (dry basis) of wheat flour in function of the extraction rate (Pederson et al., 1989)

	Extraction rate (%)						
	100	95	91	87	80	75	66
Starch + sugar (%)	69.9	73.2	75.3	77.2	80.8	82.9	84.0
Protein ($n \times 6.25$) (%)	14.2	13.9	13.8	13.8	13.4	13.5	12.7
Fat (%)	2.7	2.4	2.3	2.0	1.6	1.4	1.1
Dietary fiber (%)	12.1	9.4	7.9	5.5	3.0	2.8	2.8
Ash (%)	1.8	1.5	1.3	1.0	0.7	0.6	0.5
Energy (kJ/g)	18.5	18.5	18.5	18.5	18.5	18.4	18.3
Phosphorus (mg/g)	3.8	3.3	2.8	2.1	1.5	1.3	1.2
Calcium (mg/g)	0.44	0.43	0.38	0.33	0.27	0.25	0.23
Zinc (ppm)	29	25	21	18	12	8	8
Copper (ppm)	4.0	3.7	3.4	2.8	2.4	1.6	1.3
Iron (ppm)	35	33	28	23	15	13	10
Thiamine (µg/g)	5.8	5.4	–	4.8	3.4	2.2	1.4
Riboflavin (µg/g)	0.95	0.79	–	0.69	0.46	0.39	0.37
Niacin (µg/g)	25.2	19.3	–	10.1	5.9	5.2	3.4
Pyridoxine (µg/g)	7.5	6.6	–	3.4	1.7	1.4	1.3
Biotin (µg/g)	116	108	–	106	76	46	25
Folic acid (µg/g)	0.57	0.53	–	0.45	0.11	0.11	0.06

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