WHEAT MILLING QUALITY : INFLUENCING FACTORS AND NEW METHOD OF ASSESSMENT

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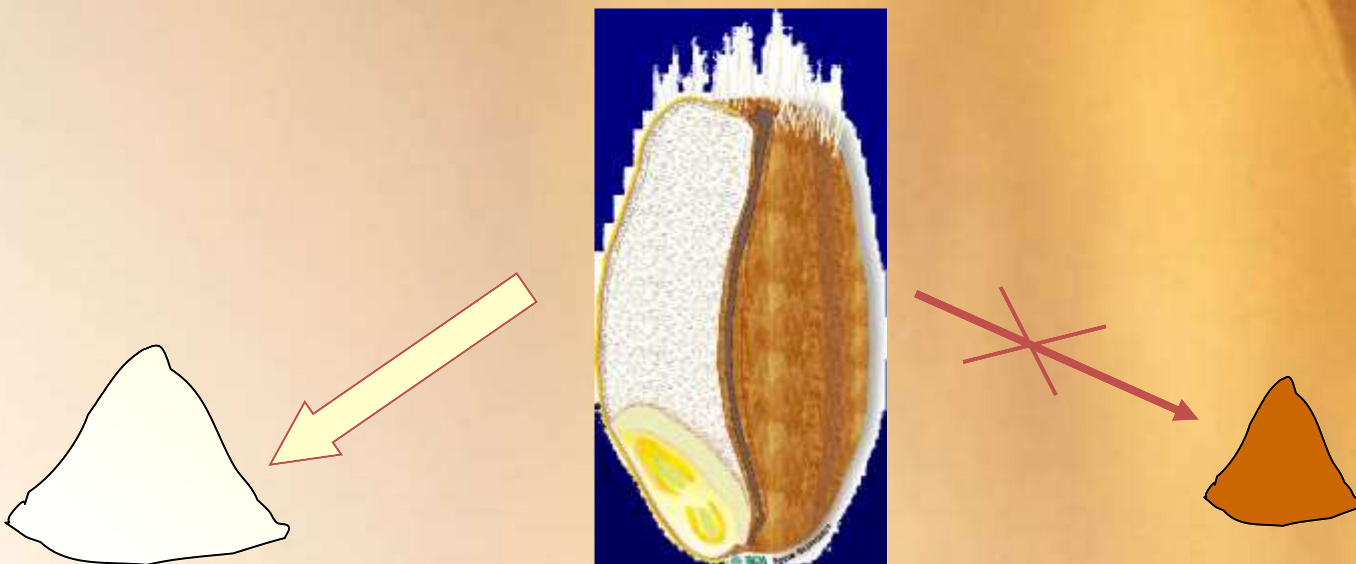
Outline

- ***To explore the structural bases of milling efficiency of wheat***
- ***To develop a small scale milling test***

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



⇑ Percentage of starchy endosperm recovered

Milling Yield

Milling Energy

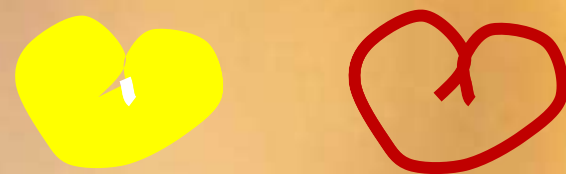
⇓ Percentage of peripheral tissues incorporated

Flour Purity

Factors of Milling Quality

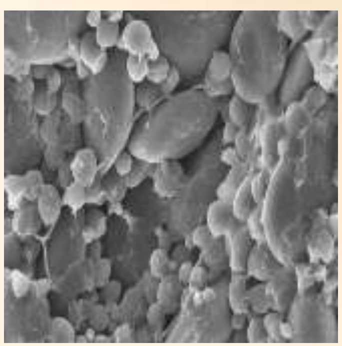
- Extrinsic factors (commercial quality)
  - Impurities, moisture content, broken kernels, ...
- Regulation factors (regulatory quality)
  - Ash content of wheat and distribution of minerals within the grain
- Intrinsic factors *(*technological quality*)*
  - Endosperm to hulls ratio
  - Endosperm texture : hardness and vitreousness
  - Easyness to separate endosperm from bran

Intrinsic Factors of the Milling Quality



Ratio
Endosperm/outer layers

Milling Value



Endosperm
Texture

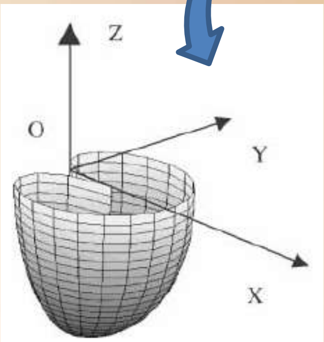
Separability
Endosperm to hulls

Endosperm to Outer Layers Ratio

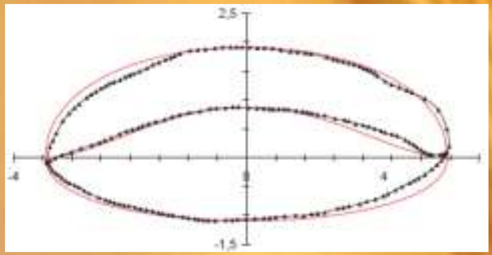
- Estimation of the flour/bran yield potential
- Not easy to determine :
  - Traditional methods : Grain size, Test weight
  - New physical methods
  - New biochemical methods

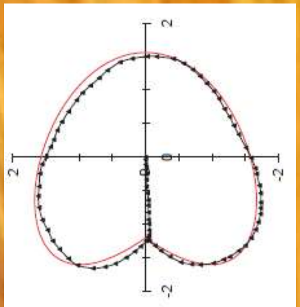
Morphological Measurements

Extraction of morphological features



3D parametric modelling of the grain



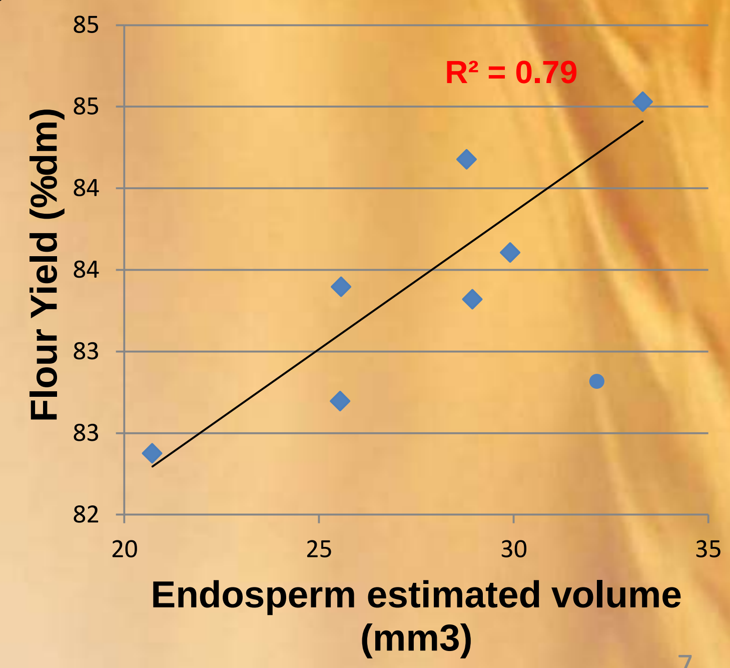


Comparison of the model with real grain sections

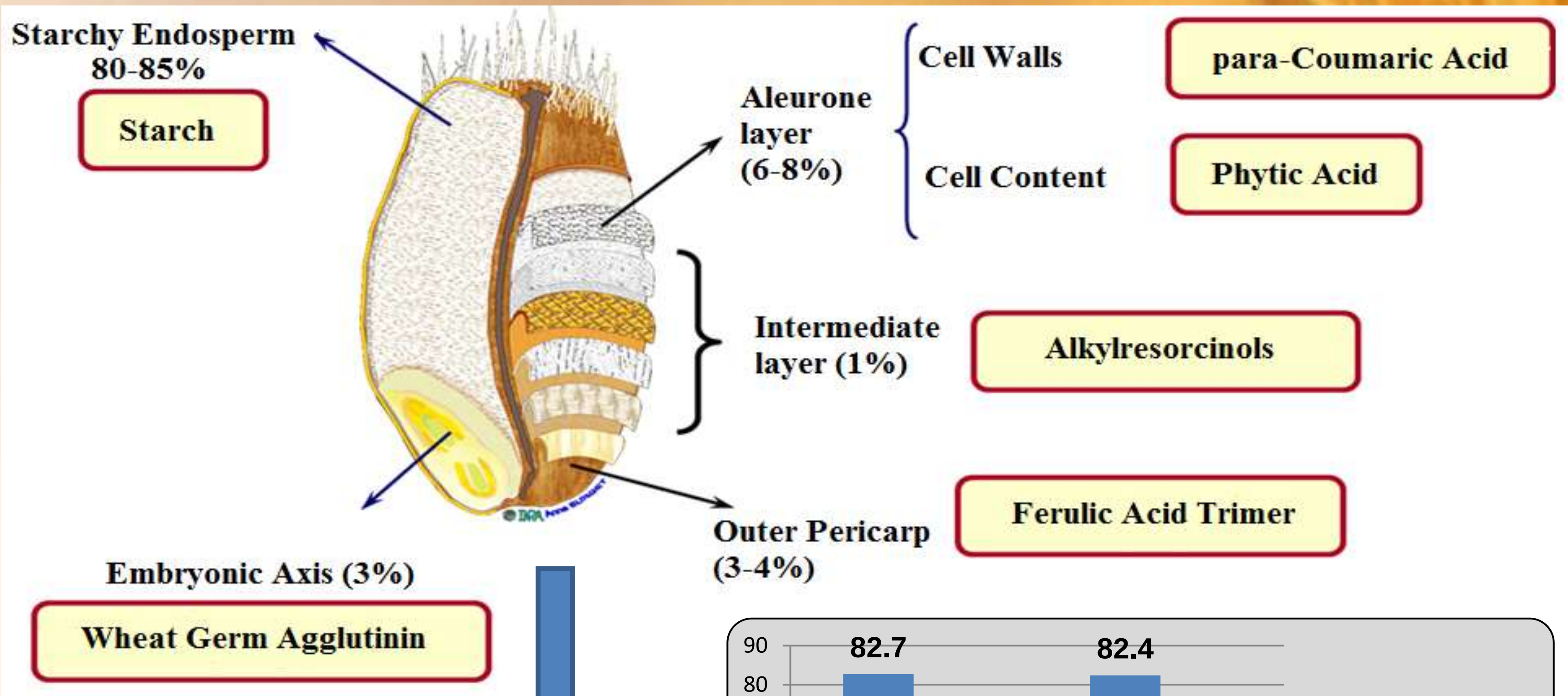
Use of the model for surface & volume determination

$V_{tot} - V_{bran} = V_{endosperm}$

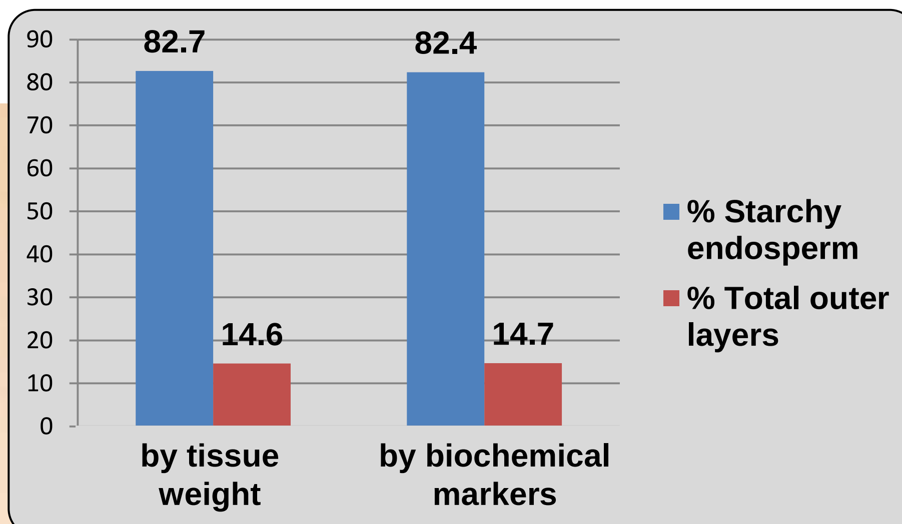
Estimation of the voluminal milling yield



Molecular Approach



$$\textbf{Tissue proportion} = \frac{100 \times [Marker]_{grain}}{[Marker]_{dissected\ tissue}}$$



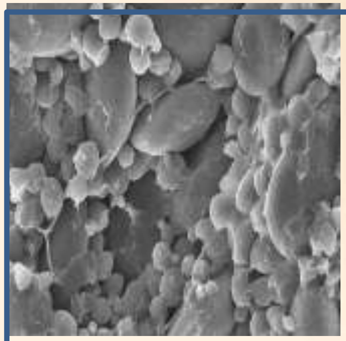
Predicting Milling Yield Using Biochemical Markers

	Pericarp (%DM)	Interm. layer (%DM)	Aleurone (%DM	Embry. axis (%DM)	Peripher. tissues (% d.m.)	Bran Yield (%DM)
A	3.4	3.1	6.9	1.0	**14.4**	**16.4**
B	3.9	3.4	6.9	0.9	**15.1**	**16.7**
C	4.0	2.0	8.5	1.0	**15.4**	**15.5**
D	4.1	2.8	7.9	1.1	**15.9**	**17.6**

Intrinsic Factors of the Milling Quality

Ratio
Endosperm/Outer Layers

Milling Value

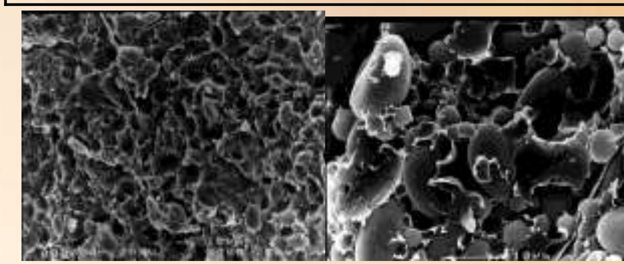


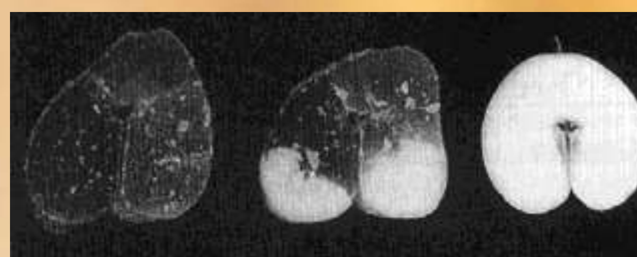
Endosperm Texture

Separability
Endosperm to hulls

Endosperm Texture

Hardness	Vitreousness
Hard / soft	Vitreous/ floury
Physical	Optical
Genetic	Agronomy

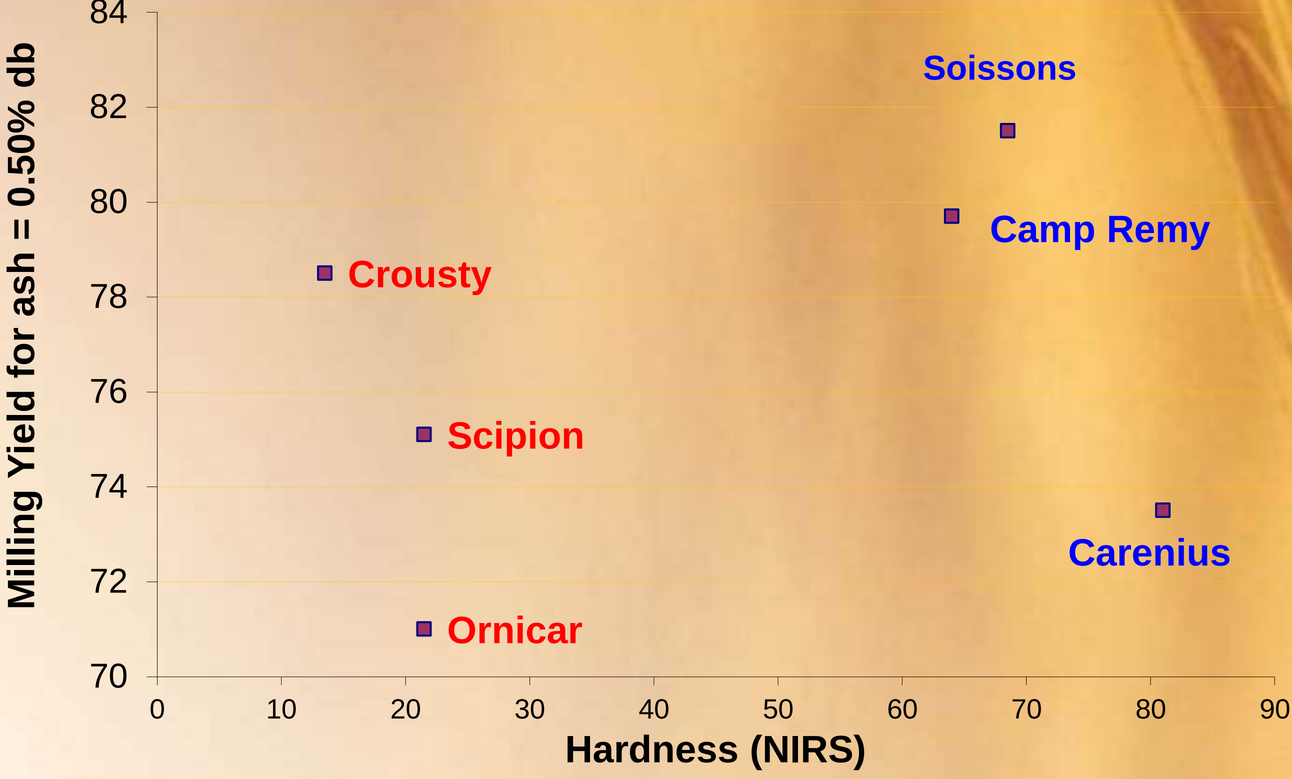




How hardness and vitreousness affect

milling behaviour ?

Milling Quality for Some Cultivars



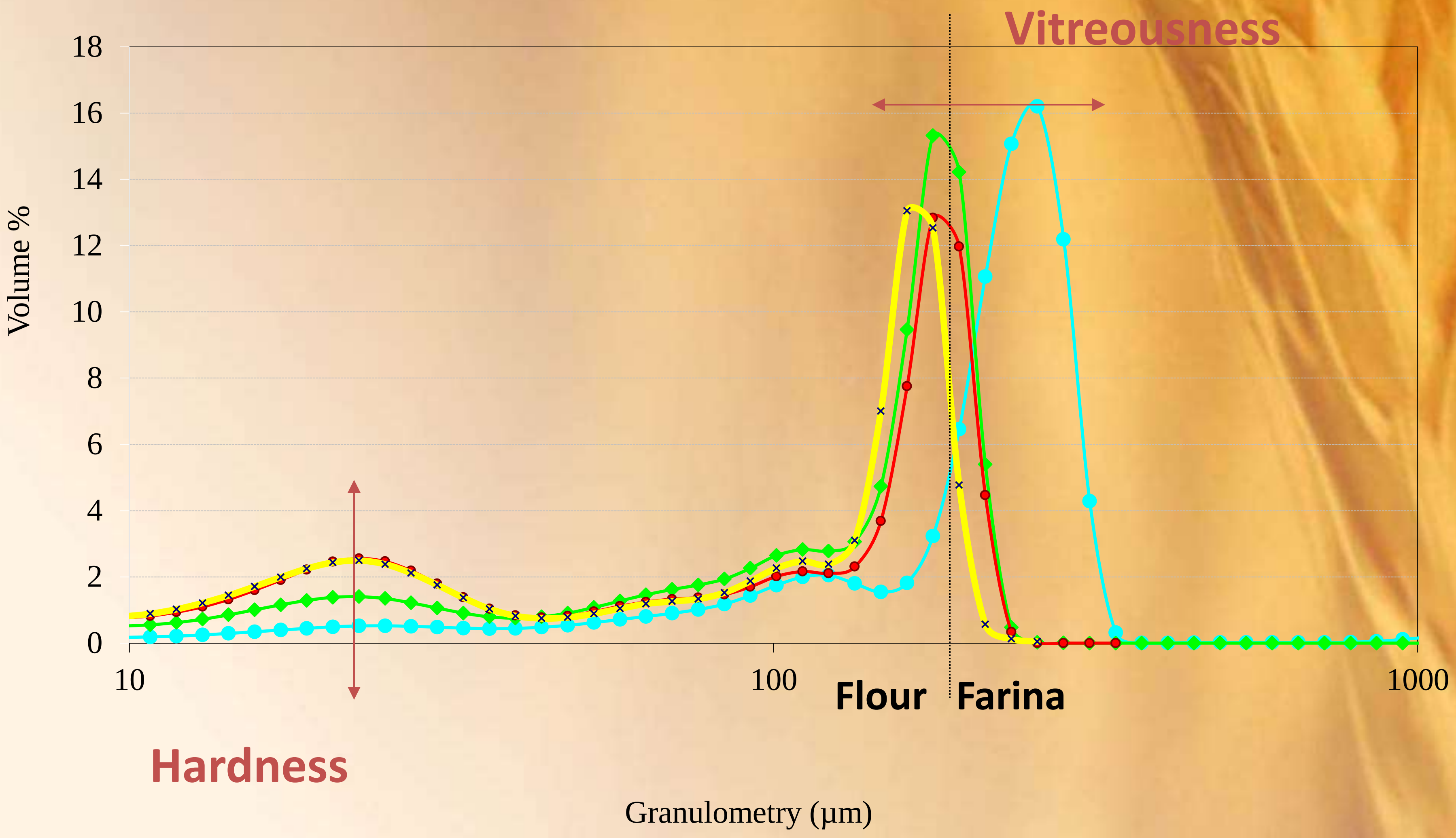
Some differences between hard and soft wheat types

Larger differences within a same wheat type

Impact of Hardness on Milling Behavior

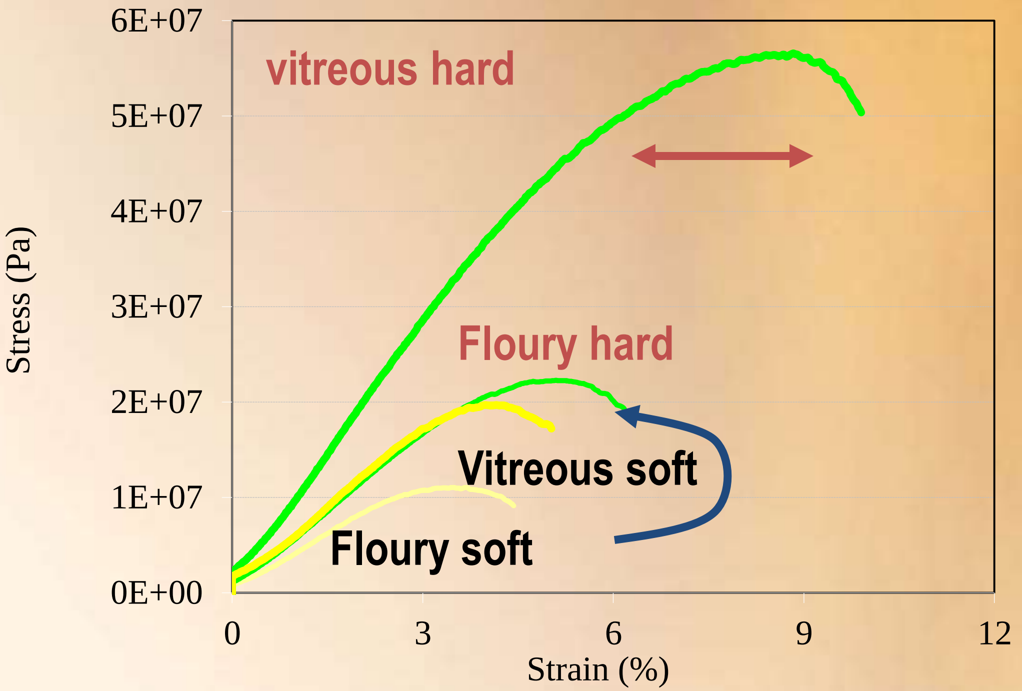
	Hard	Soft
Break Flour	-	+++
Sizing Flour	++	++
Reduction Flour	+++	+
Semolina Production	+++	-
Large Bran / Total bran	-	+
Total flour yield	+	+

Granulometry of Reduction Streams



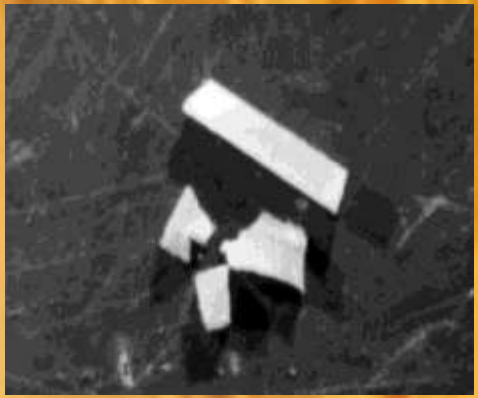
Mechanical Properties of Endosperm

Hard and vitreous : ⇑ extensibility

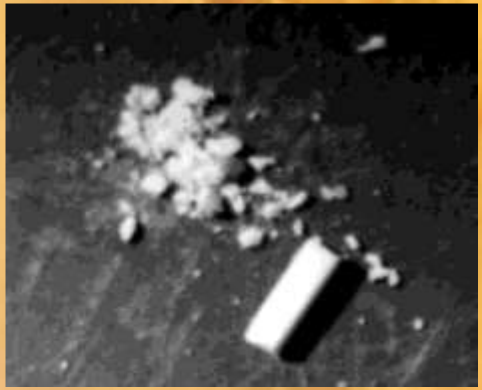


⇑ Hardness = ⇑ Failure Stress

Ductile



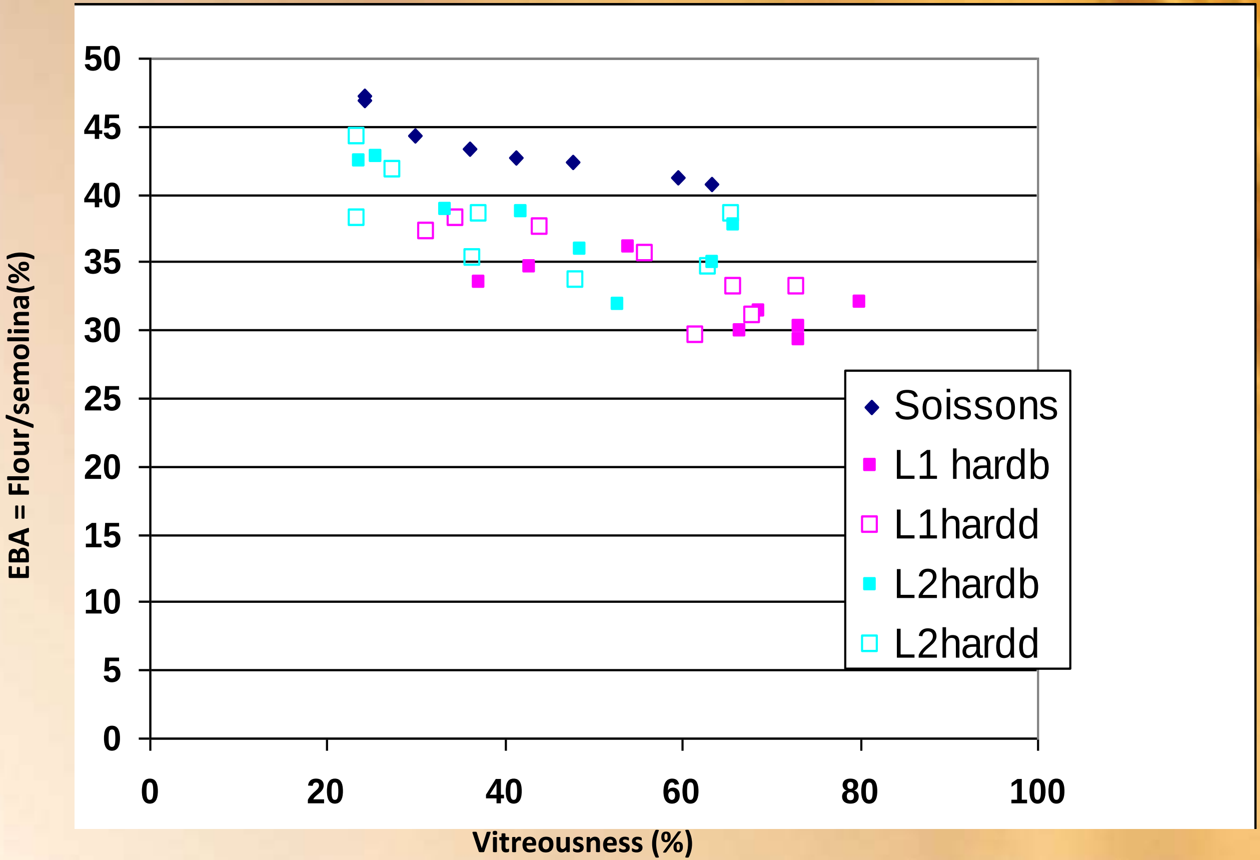
Fragile



Mechanical properties of endosperm =

Indicator of easyness of endosperm to be reduced into flour

Endosperm Breakage Ability



EBA depends on vitreousness

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

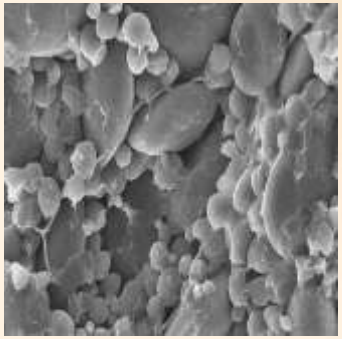
Endosperm Texture

- 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

Ratio
Endosperm/Outer Layers

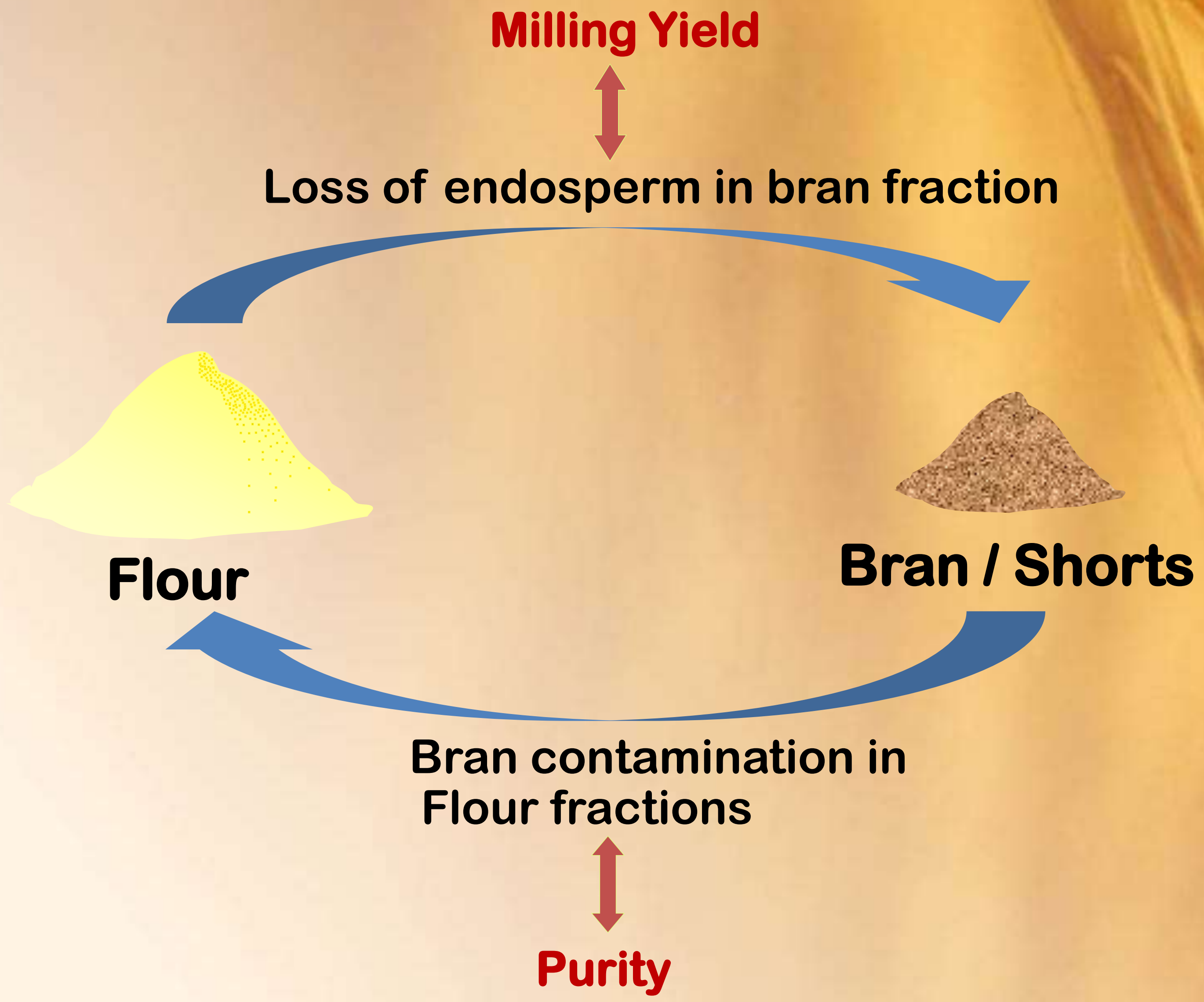
Milling Value



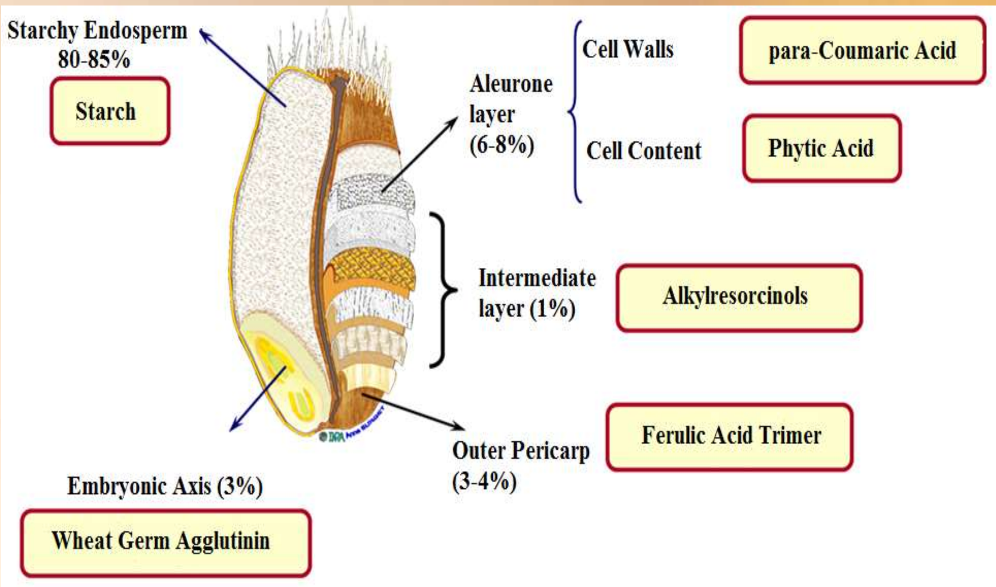
Endosperm
Texture

Separability
Endosperm to hulls

Concept of Separability



Separability Endosperm – bran



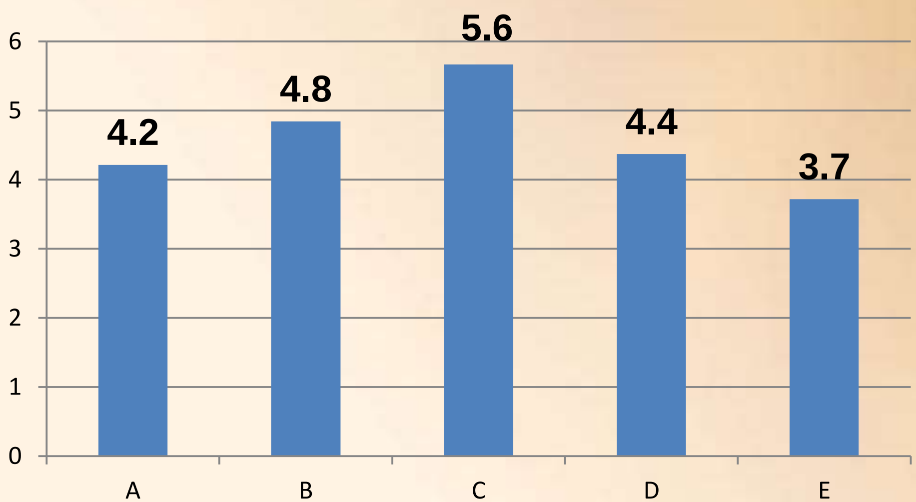
Separability Index

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

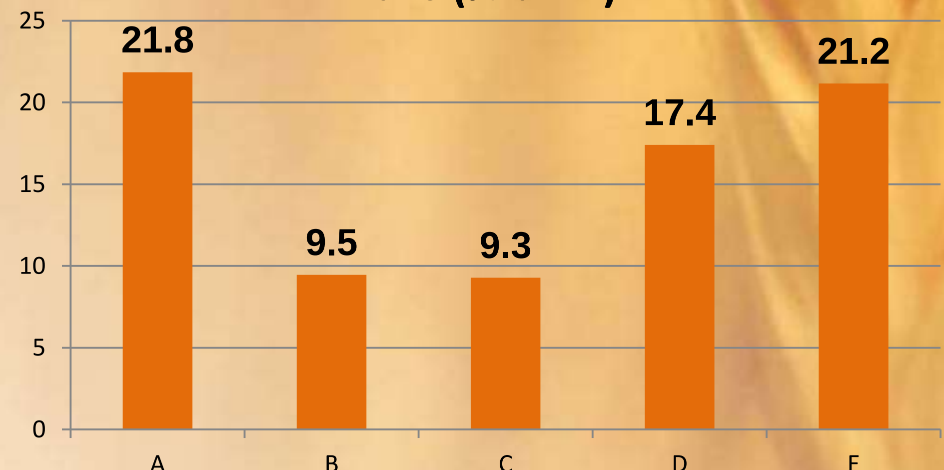
Relative proportions of extracted:

- Endosperm (%E)
- Aleurone (%A)
- Pericarp (%P)

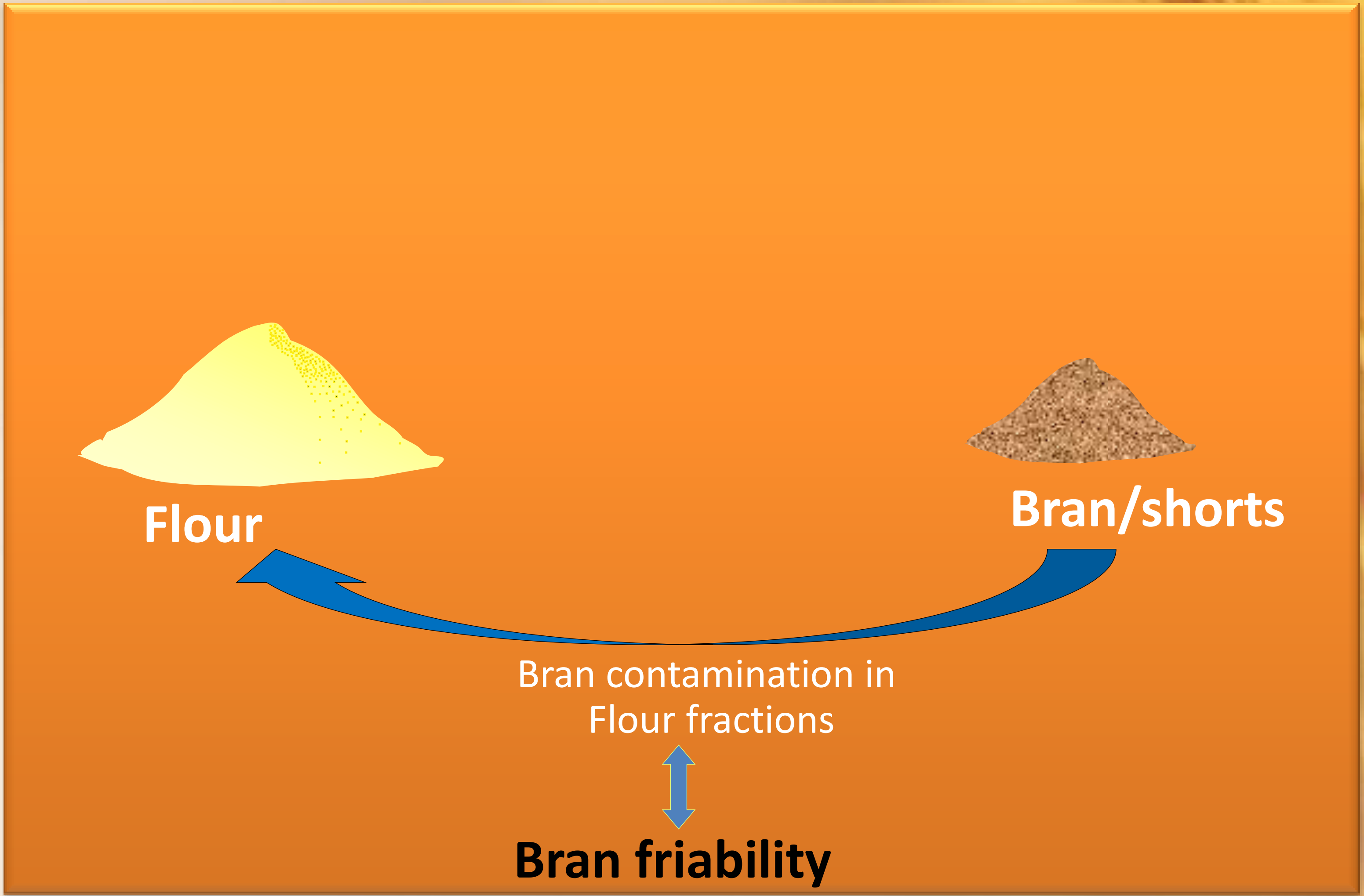
Loss of Endosperm in Bran (% d.m.)



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

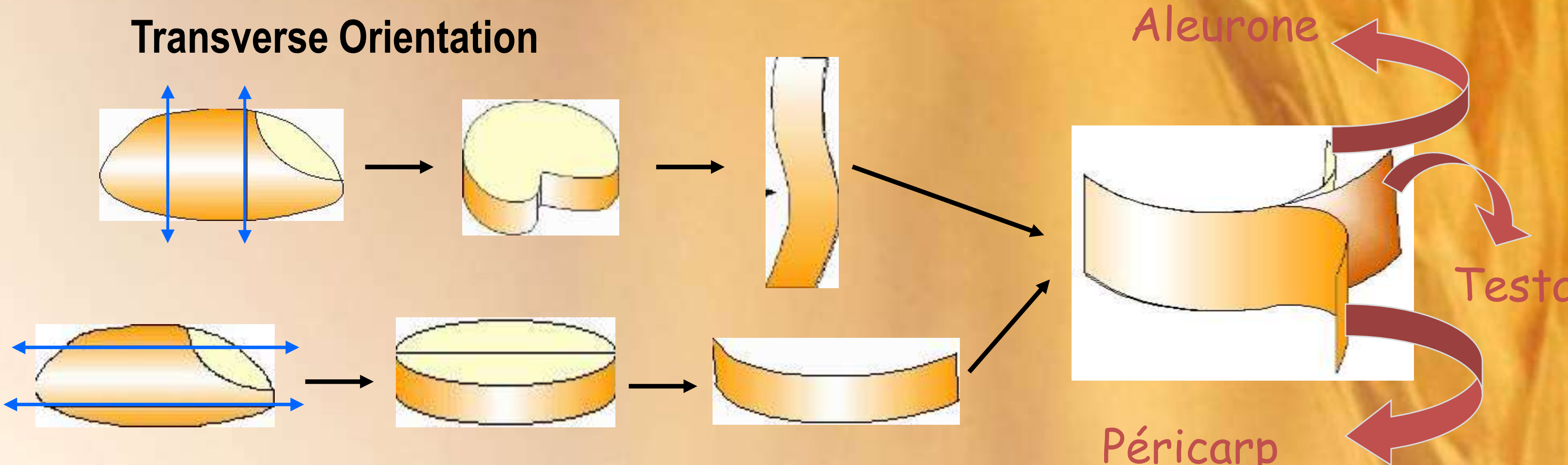


Endosperm-Bran Separability Influencing Factors



Mechanical Properties of Grain Hulls

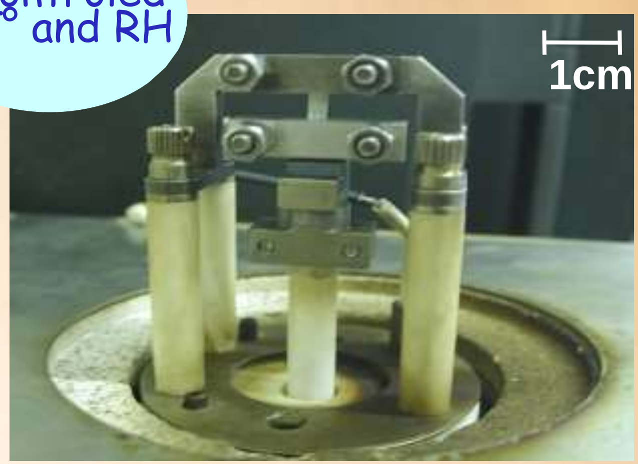
Transverse Orientation

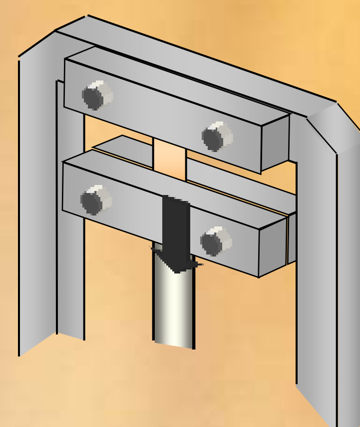


Longitudinal orientation

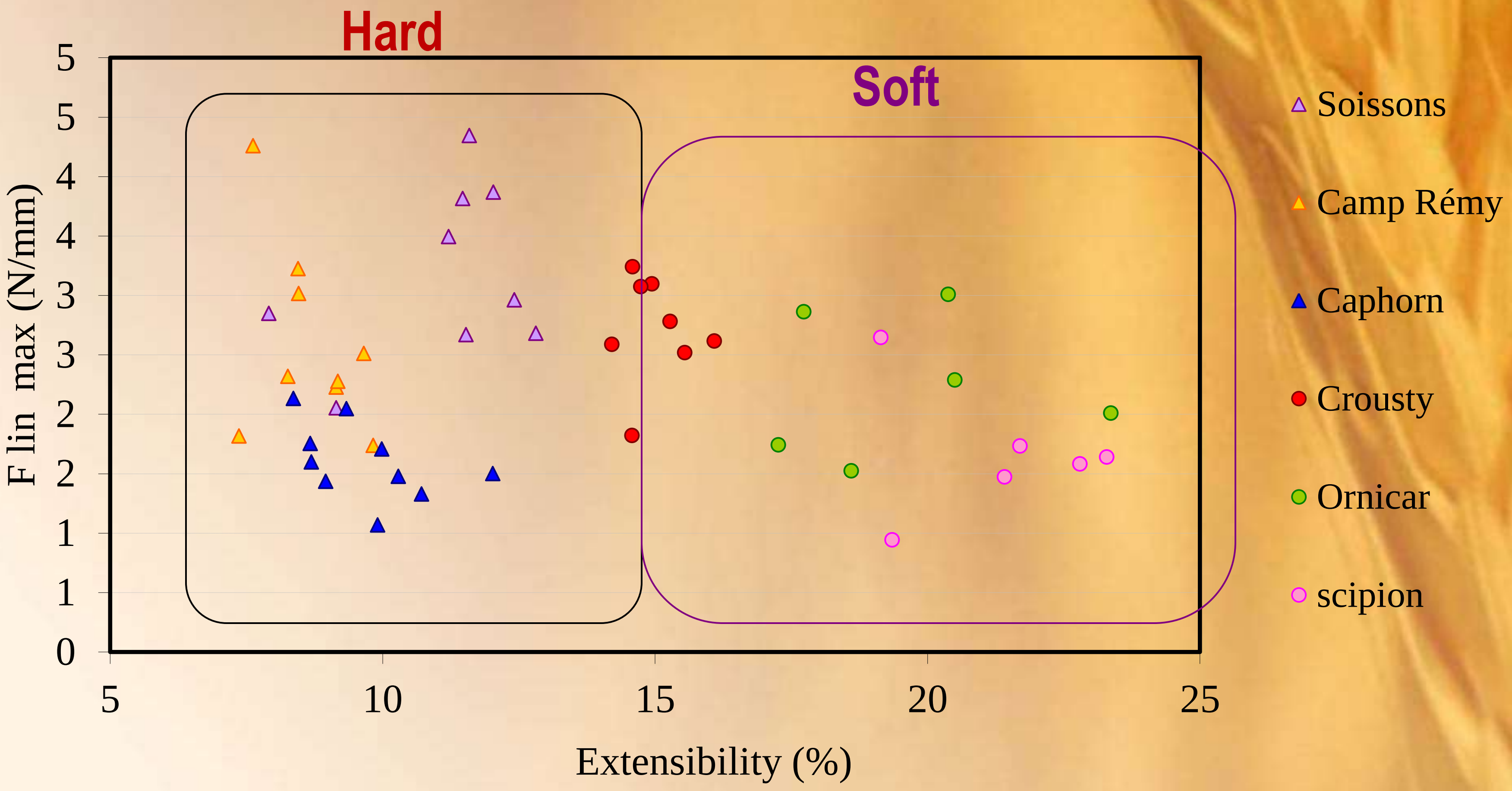
Traction Tests

Controled T° and RH



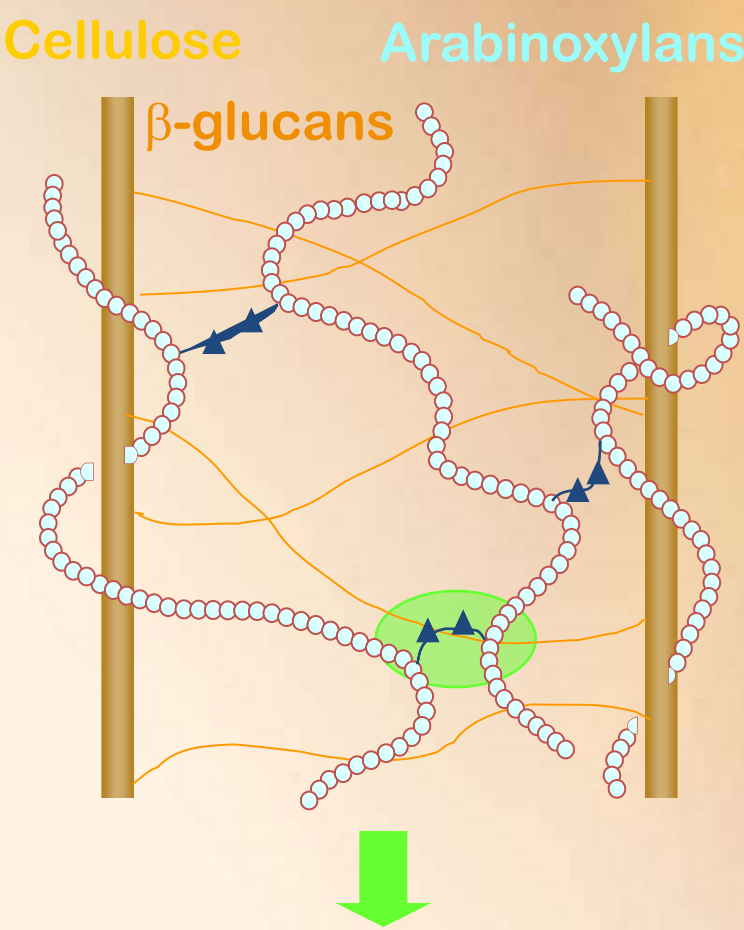


Mechanical Properties of Hulls

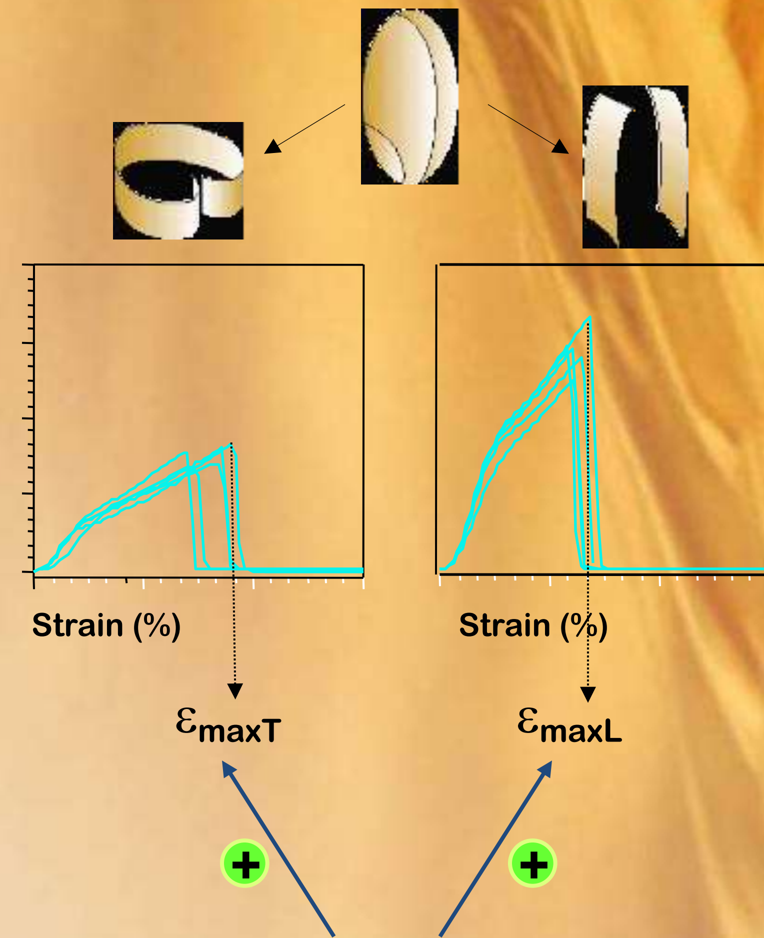


Large variability between hard and soft wheats and within each type of heat

Influence of Cell Wall Polysaccharide Organization on Mechanical Properties



Degree of arabinoxylan cross-linking in the cell wall

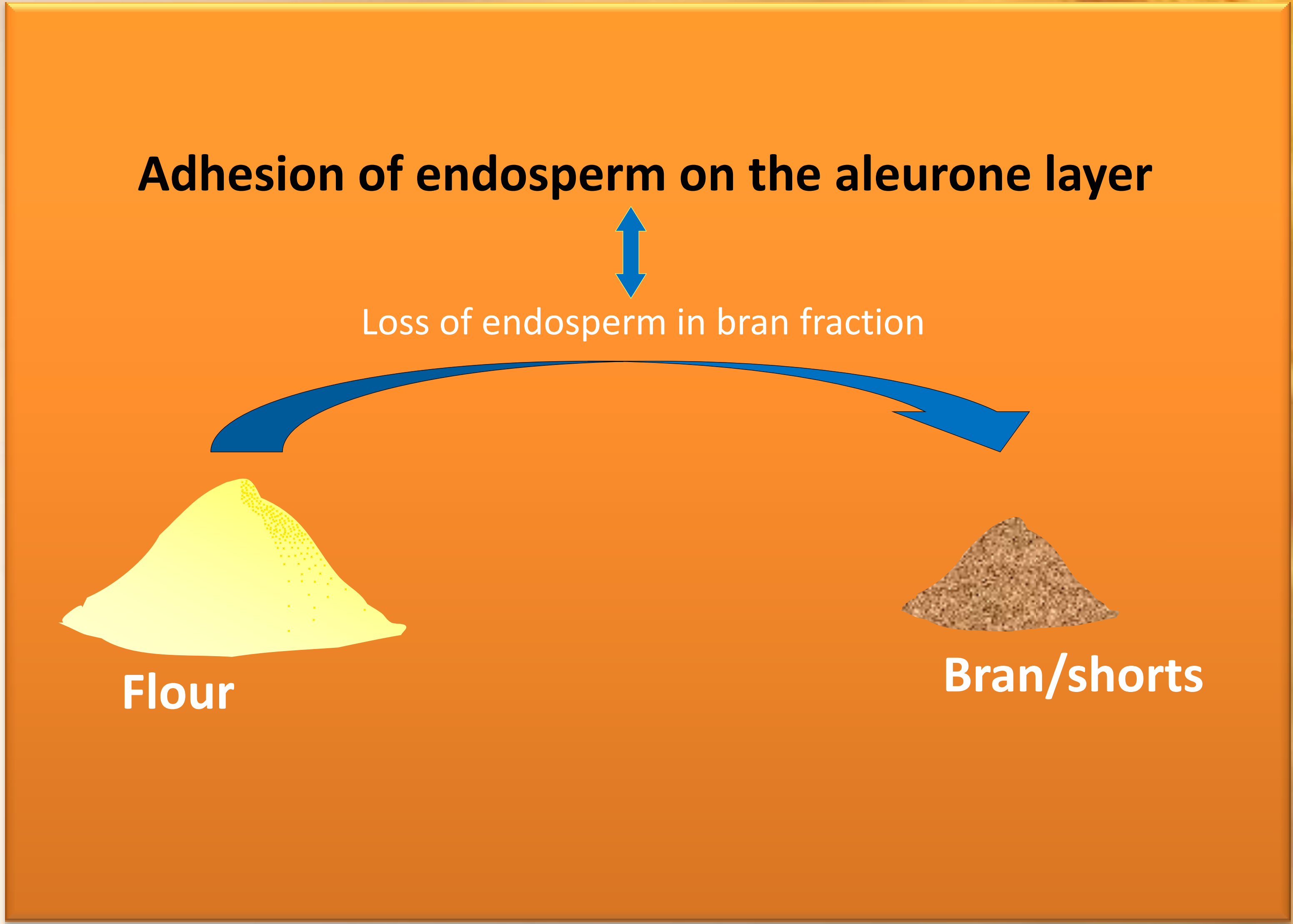


$$= \frac{DHD}{Xyl}$$

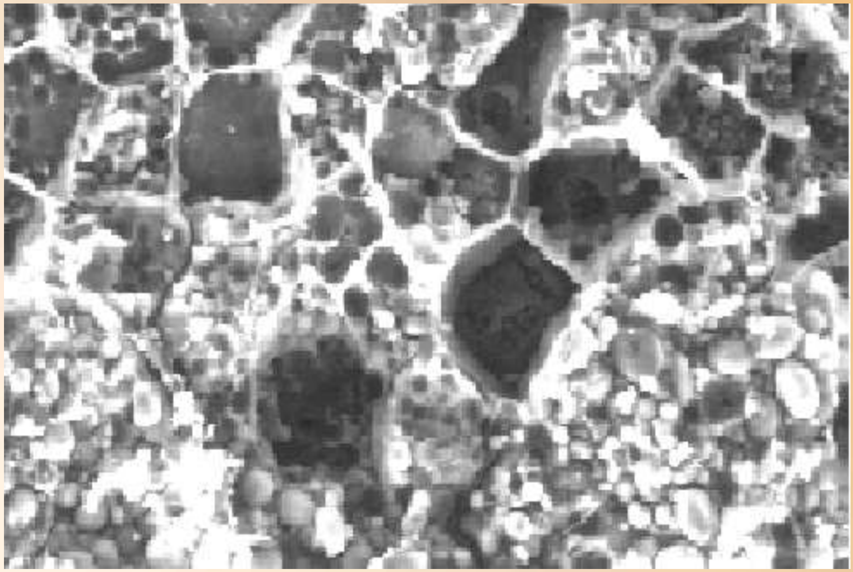
Bran Contamination into Flours

- 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

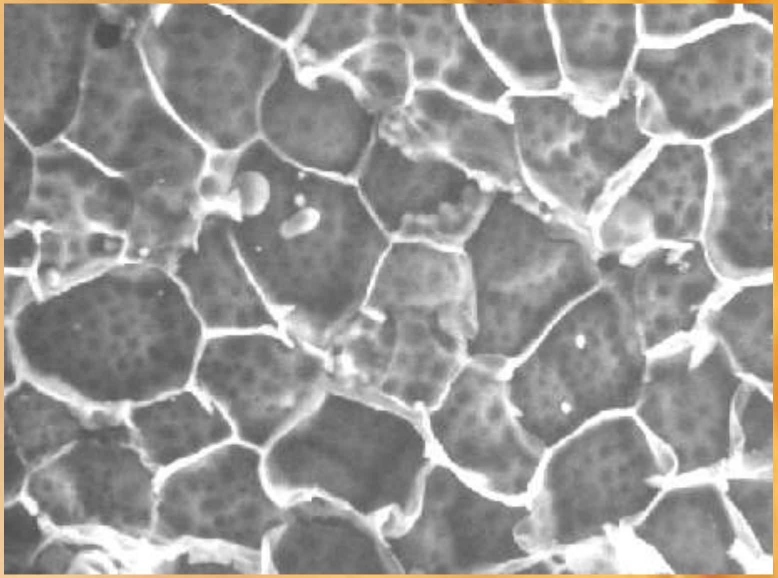
Influencing factors for endosperm-bran separability



Bran Internal View



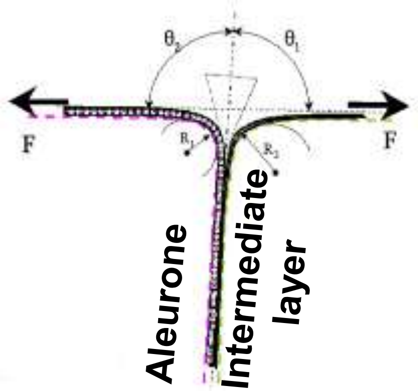
Soft



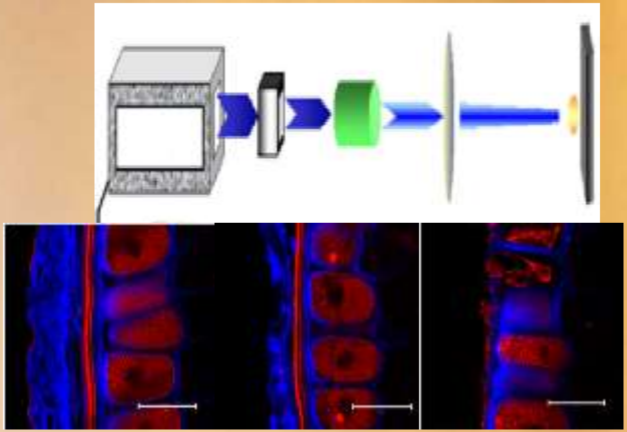
Hard

Adhesion Between Wheat Tissues

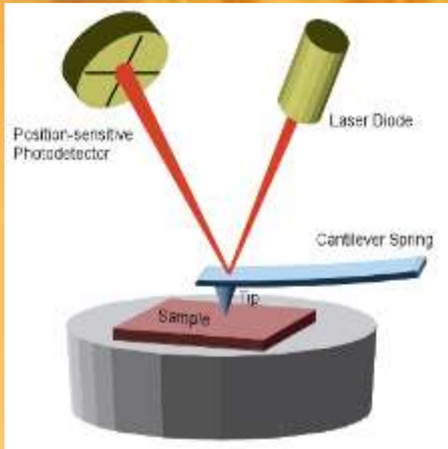
- **Adhesion force between tissues**



Peeling tests

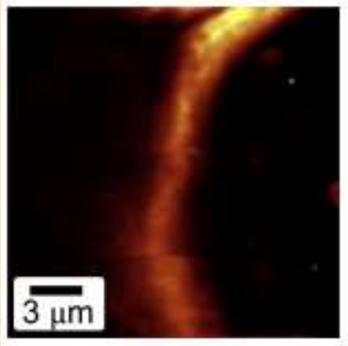


Pulsed-Laser Ablation

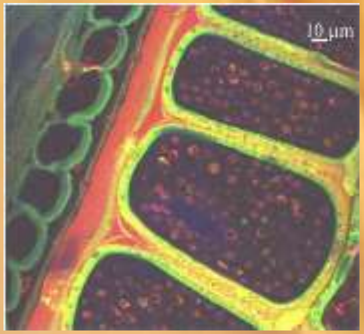


Atomic-Force Microscopy

- **Local composition analysis**



Raman Microscopy



Immunolocalization

Endosperm-aleurone border *Jääskeläinen et al., 2013,*

INRA, BIA

Predicting the Milling Quality

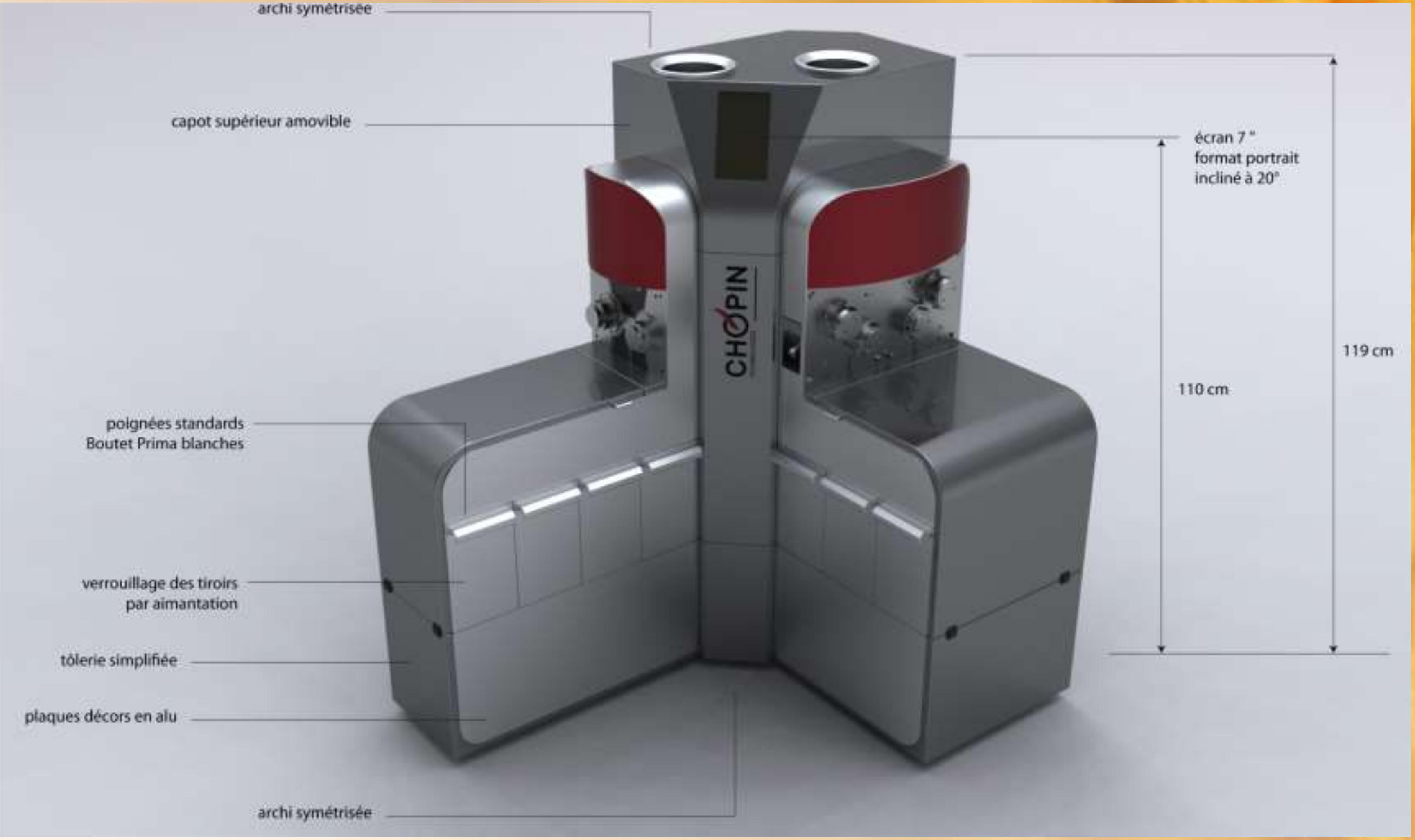
- Several influencing factors affect milling operations, milling yield and flour purity
- Influencing factors may interact
- All these factors must be taken into account to develop a milling test.

2. Development of a New Test Mill

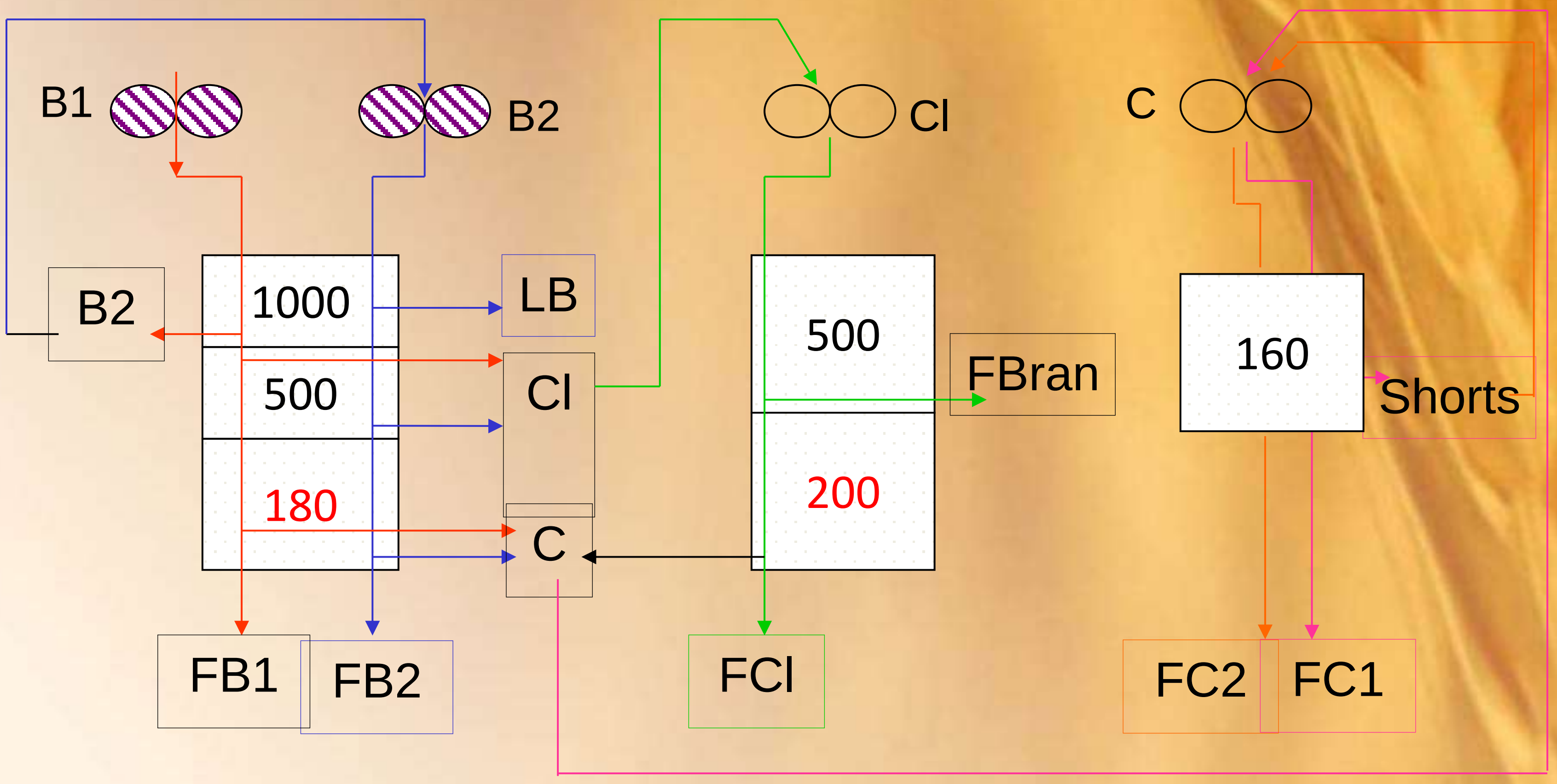
Aims

- 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

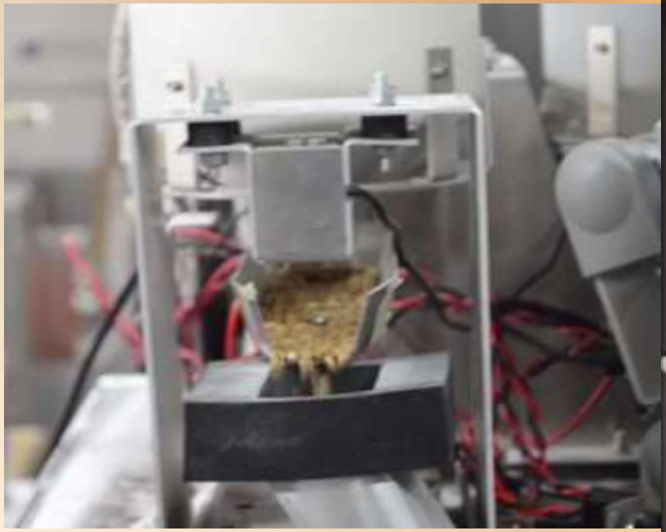


A Specific Milling Diagram (Patent)



- **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

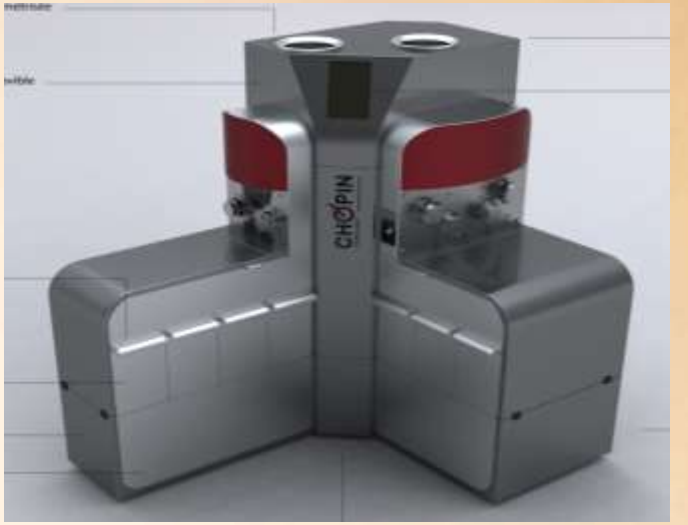
2. Roll speed control

3. Adjustable roll gaps

4. Improved centrifuge sifting

Performances of the New Chopin Lab-Mill

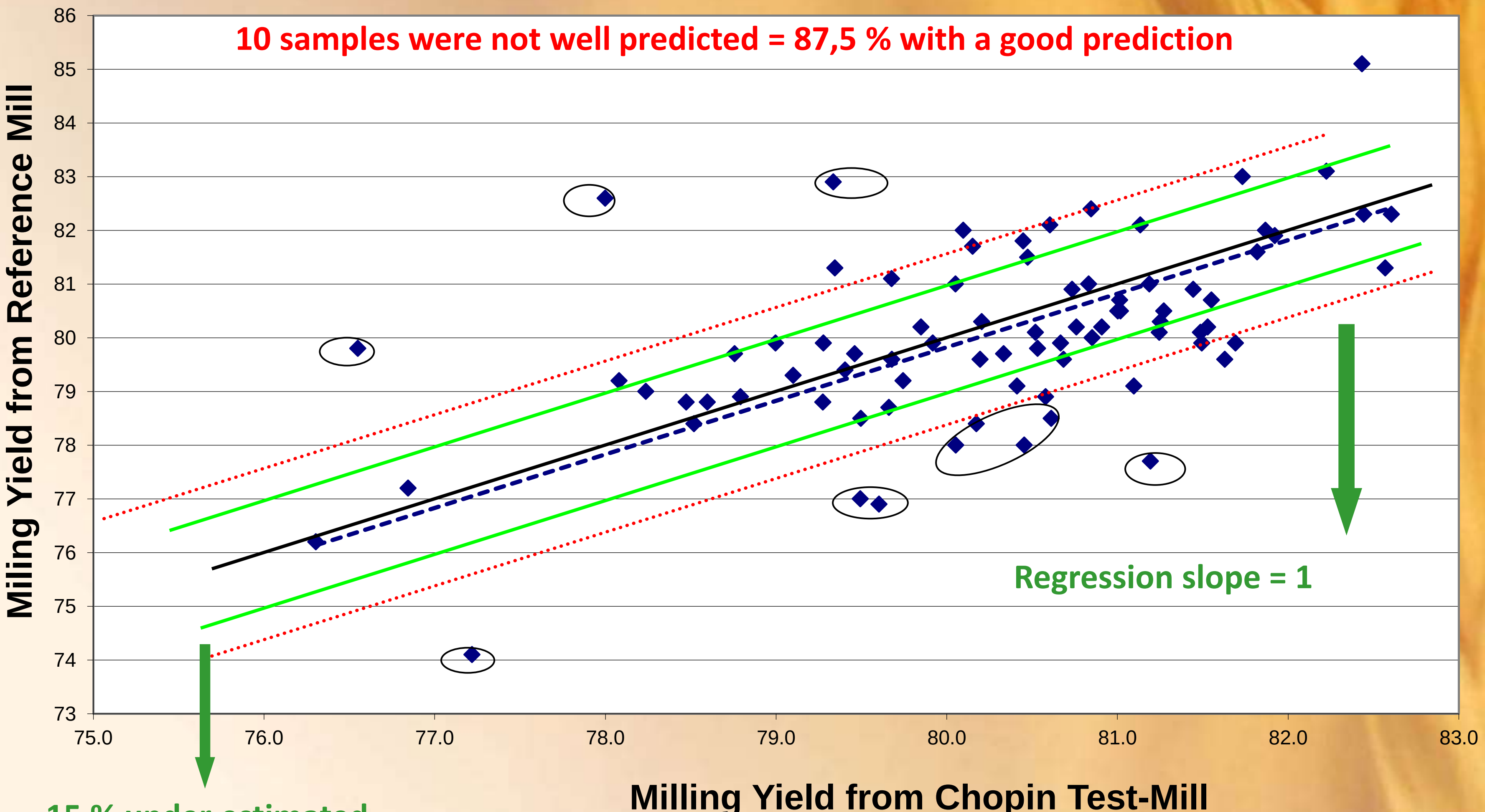
- Comparison of milling performances with a reference mill
- Variability of wheat milling efficiency
- Flour quality



Chopin new Lab Mill

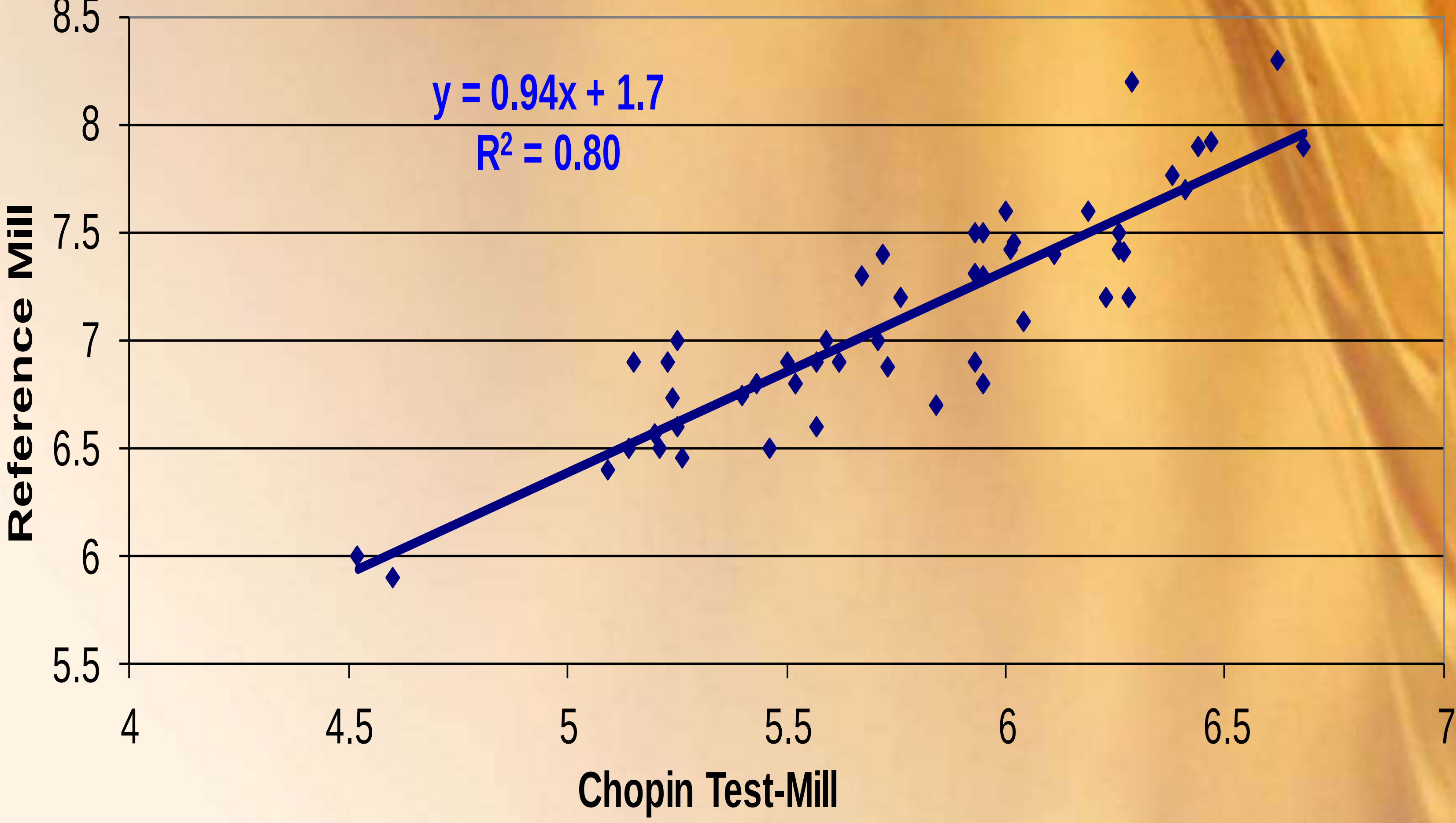
French Milling School in Surgères

Prediction of the Milling Yield

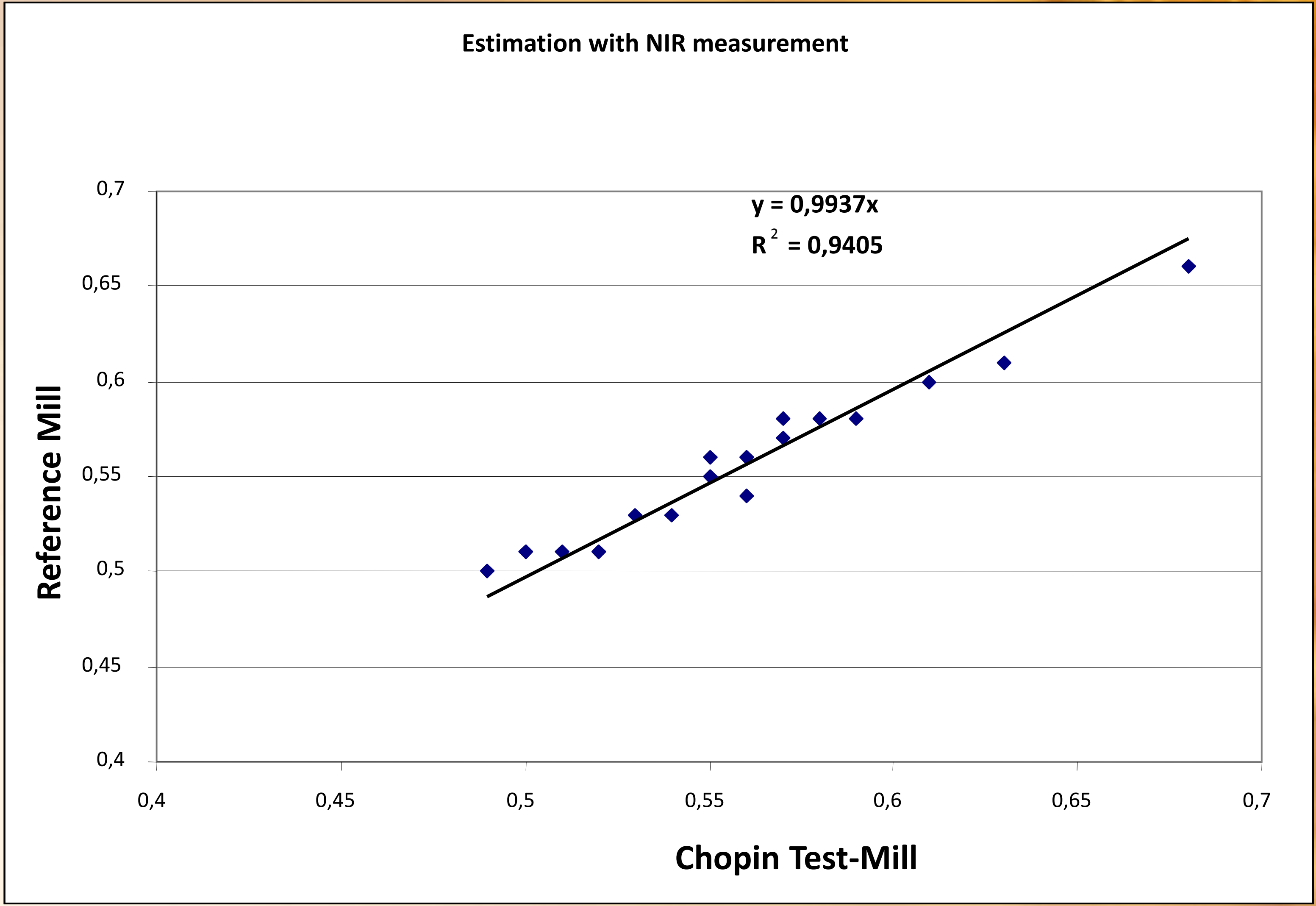


15 % under estimated
21 % over-estimated
64 % well predicted

Prediction of Bran Ash Content

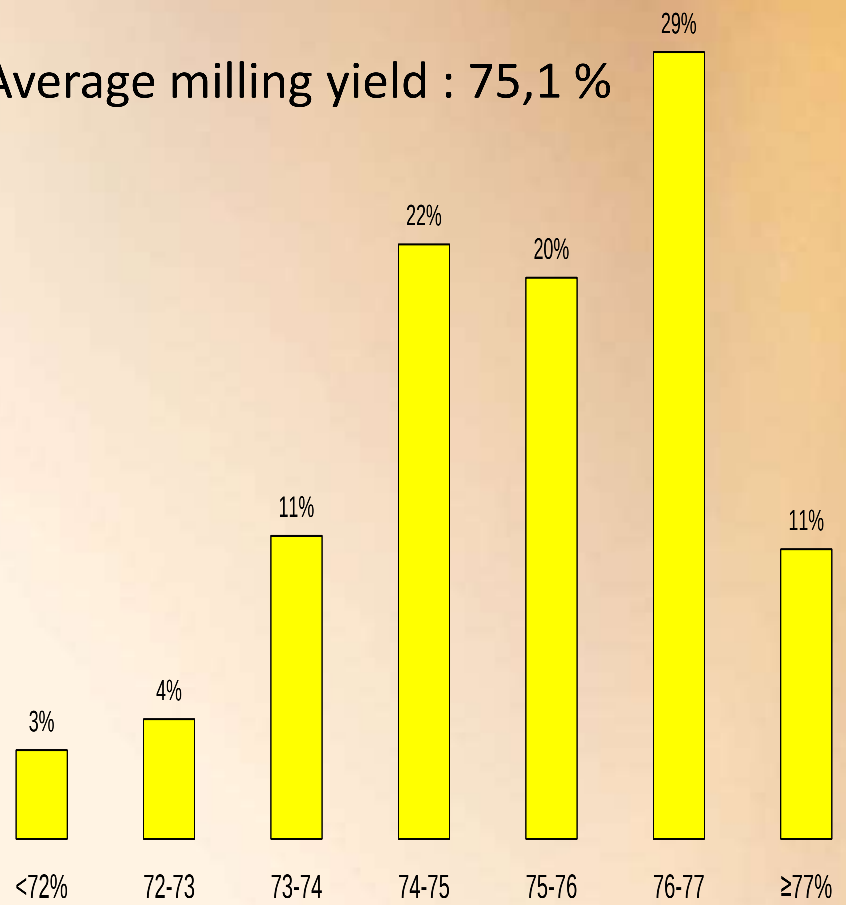


Flour Ash Content



Reliability of the Chopin Test-Mill

Average milling yield : 75,1 %

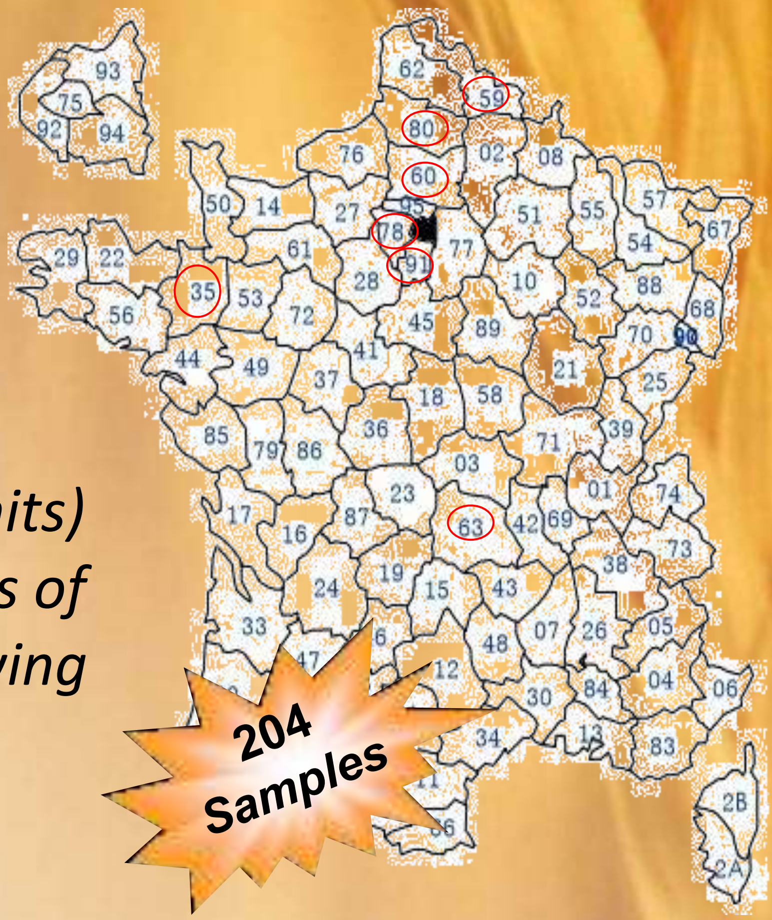


Issues	Average Value	Standard Deviation	C.V. (%)
% FB1	16,8	0,2	1,0
% FB 2	11,7	0,1	1,1
% F Cl	8,9	0,3	3,4
% F C1	33,0	0,4	1,0
% FC2	5,4	0,2	3,4
% L bran	11,7	0,4	3,4
% F. bran	5,8	0,2	4,0
% Shorts	6,2	0,2	2,4
% Total Flour	**75,7**	**0,2**	**2**

A reliable tool on a large set of samples and with different operators

Genetic and Environmental Effects on Wheat Milling Quality

- *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

Milling Yield > 79 %	**Soissons (80.1)**
	Apache (79.7)
	Euclide (80)
	Isengrain (79.5)
	Perfector (79.1)
	Bermude (79)
Milling Yield	All others
Milling Yield < 76.8 %	**Carenius (76.8)**
	Oackley (76.6)
	Orvantis (76.4)
	Quebon (75.1)
	Timber (75.5)

Soft Type

Cultivar (Hardness)	Total Flour (%)
Crousty (20)	**77.1**
Robigus (15.5)	76.1
Ressor (15.5)	75.9
SC 4013 (31)	74.75
Paledor (10.3)	74.75
Astuce (13.4)	74
Innov (6)	**71.4**

Alveographic Properties of the flour obtained with the Chopin Test-Mill

		W		G		P/L	
	Origin		SD	moy	SD	moy	SD
Soft	N+	133	23	25,03	2	0,31	0,1
	N	103	6	25,13	1	0,24	0,1
b	N+	256	56	23,60	2	0,66	0,2
	N	254	75	24,23	3	0,69	0,3
c	N+	238	97	21,63	4	0,90	0,3
	N	174	51	19,98	3	0,94	0,3
d	N+	225	22	23,75	3	0,59	0,2
	N	164	85	22,20	2	0,60	0,1

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 developped to propose a fast screening system to answer breeders demand as well as for grading systems and millers requirements.

Acknowledgements

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