

## **Durum Wheat Milling: Influence of genetic and agronomic factors**

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Nine varieties of varied grain size and vitreousness were grown during two years according to different modes in order to cause either a nitrogen deficiency or a water stress. The yields in semolina, flour and bran obtained in a pilot semolina (150 kg / h) indicated that the semolina value of durum wheats essentially depends on genetic factors, whereas growing conditions essentially influence endosperm hardness and flour percentage. Ash content turned out to be inadequate for accurately measuring milling streams purity since it directly depends on ash content of the processed wheat grains.

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# Durum Wheat Milling: Influence of Genetic and Agronomical Factors

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Thank you Mr. Chairman,

Dear Colleagues, I am glad to be with you this afternoon to discuss some problems on durum wheat milling and influence of genetic and agronomical factors, a paper that is co-authored by our thesis student Isabelle Lempereur and my coworkers Pierre Feillet, Joël Abecassis and Marc Chaurand

## Semolina Value

\* Ease with which durum wheat kernels can be milled into semolina and yield of pure semolina that can be extracted

\* Depends on three groups of factors:

- Commercial condition of grain (humidity, impurities, broken kernels,...)
- Intrinsic factors, or technological quality (ratio endosperm/bran layers, endosperm friability, ease to separate endosperm and bran layers)
- Regulation: ash content of wheats and distribution of ash in the kernel



Semolina value can be defined by a concept of Ease with which durum wheat kernels can be milled into semolina and yield of pure semolina that can be extracted

It depends on three groups of factors:

- Commercial condition of grain (humidity, impurities, broken kernels,...)
- Intrinsic factors, or technological quality (ratio endosperm/bran layers, endosperm friability, ease to separate endosperm and bran layers)
- Regulation factors of semolina purity, based on ash content of wheats and distribution of ash in the kernel

- However, studies on the first transformation and on semolina value have remained insufficient:
- The exact influence of varietal or agronomical factors on semolina value are not really known.
- Its physical or physico-chemical bases are still controversial.
- No efficient micro test for semolina value designed to durum wheat breeders is available.

There is generally an agreement on these general concepts.

However, in comparison to studies aimed at improving durum wheat for pasta quality (I mean color, cooking quality), studies on the first transformation and on semolina value have remained insufficient:

- The exact influence of varietal or agronomical factors on semolina value are not really known.
- Its physical or physico-chemical bases are still controversial.
- In contrast to the numerous breeding tests for color or cooking quality, no efficient micro test for semolina value designed to durum wheat breeders is available.

## Objectives

- **Main objective: Define criteria to assess semolina value in breeding programmes**
- **Specific objectives:**
  - Influence of genetic/agronomical factors on size, shape, texture or histological composition
  - Link morphological and textural characteristics to yields in semolina, flour and middlings
  - Origine of differences in milling behaviour through study of ash distribution
  - Micro test for prediction of semolina value in breeding

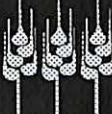


Therefore, the main objective of this study was to define criteria to assess semolina value in breeding programmes

More specifically:

- To investigate the influence of genetic/agronomical factors on size, shape, texture or histological composition
- To determine the link of morphological and textural characteristics to yields in semolina, flour and middlings
- To determine the origine of differences in milling behaviour through distribution of ash and cell-wall components
- And, in a more longer term, to design a micro test for prediction of semolina value in breeding

## Experimental Design




● **Varietal influence: 9 cultivars**

Vitreousness	Thousand-kernel-weight		
	small	medium	large
low	<i>Primadur</i> <i>Cando</i>	<i>Ambral</i>	<i>Agridur</i>
medium		<i>Agrial</i> <i>Exodur</i>	<i>Ardente</i>
high	<i>Arcour</i>	<i>Capdur</i>	

● **Agronomical influence: 2 modes**

- Water stress
- Nitrogen fertilisation

→ 72 durum wheat samples over 2 harvest years



The study was based on the following experimental design :

- 9 cultivars
- 2 modes of growing

## Methods

- Experimental milling of 200-kg samples (INRA semolina pilot plant, Montpellier): tempering to 17%, 5 break rolls, 4 sizing rolls, 3 plansichters, 3 double purifiers

– 6 semolinas, 4 break flours, 4 sizing flours, 4 middlings

- Grain characterisation: protein, ash, vitreousness, test weight, 1000-kernel weight, hardness, size

- Chemical analyses: ash, cell wall components, pentosans, ferulic acid, fluorescence and NIR spectroscopy



The experimental design was also novel because for the first time pilot experiments on 200 kg were applied on as many as 72 samples. This was carried out at the INRA semolina pilot plant in Montpellier which consists of 5 break rolls, 4 sizing rolls, 3 plansichters and 3 double purifiers.

This allowed separation of 6 semolinas, 4 break flours, 4 sizing flours and 4 middlings

- Grains were characterised by: protein, ash, vitreousness, test weight, 1000-kernel weight, hardness, size and by the following chemical analyses: ash, cell wall components, pentosans, ferulic acid, fluorescence and NIR spectroscopy

Grain Characteristics				
Cultivars	1000-K-W	T-W	Protein	Vitreousness
● Ambral	35	80	13.9	54
● Arcour	33	81	14.8	81
● Ardente	42	80	14.3	64
● Cando	28	79	13.5	47
● Capdur	35	81	14.3	77
● Primadur	26	77	13.9	61
● ...				
<i>F (Cultivar)</i>	****	****	**	****

Now, let me show a few results that we have extracted from our experimental study.

In a first (main) part, I will illustrate influence of agronomical and genetic factors.

In a second short part, I will give some trends of the results on physico-chemistry of cell-wall components.

From this table on grain characteristics, we can see that cultivars strongly differ in kernel weight (also in test weight and vitreousness) and that two of them (Cando and Primadur) even have 1000-kernel-weights inferior to 30 grams

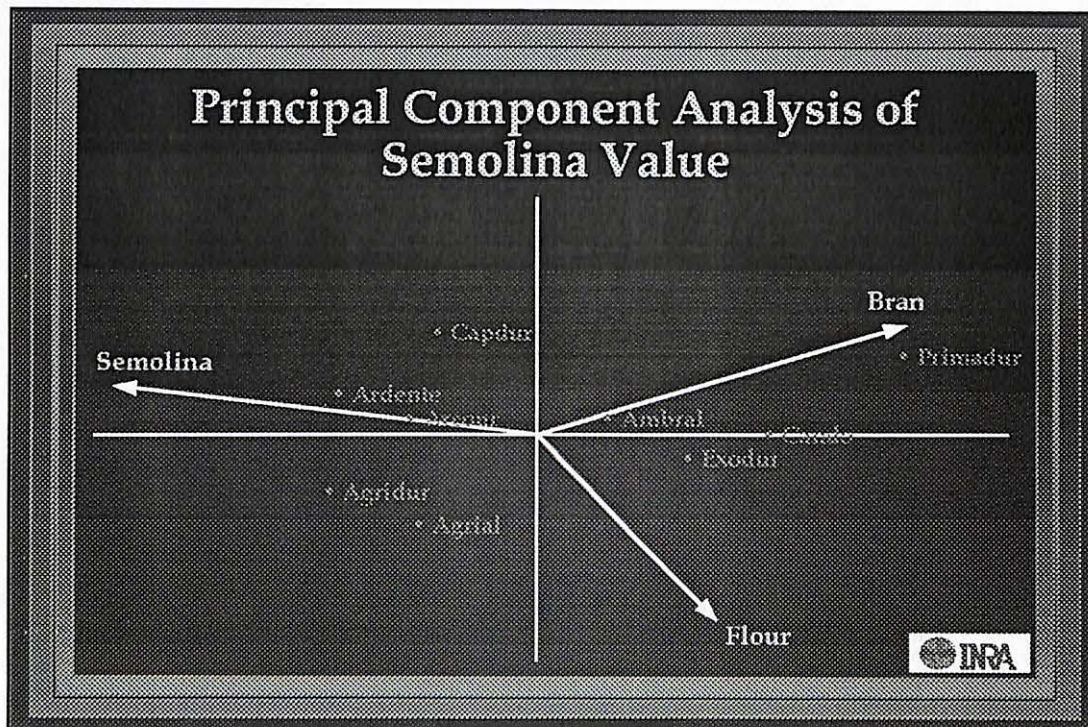


### Influence of Genetic and Agronomical Factors on Milling Yields (% d.b.)

Cultivars	Semolina	(C/F)	Flour	Bran
● Ambral	74.1	(7.8)	8.3	17.6
● Arcour	75.9	(8.3)	7.5	16.7
● Ardente	75.8	(7.9)	7.9	16.2
● Cando	72.5	(7.7)	8.3	19.1
● Capdur	75.4	(7.7)	7.0	17.6
● Primadur	70.6	(6.5)	8.2	21.1
● ...				
<i>F (Cultivar)</i>	****	****	*	****

Looking now at milling yields, it is easy to observe that cultivars (mean value of each cultivar, all growing modes averaged) also differed in semolina yields, ratio coarse/fine semolina and bran percentage, but not significantly in flour percentage.

This is an economically major result, considering that, for instance, 1 percent difference in semolina yield is equivalent to \$ 1,000,000 per year for a big French semolina factory. So using cultivars with kernel weight inferior to 30 grammes certainly has negative consequences for the semolina industry.



This simplified PCA illustrates the trends in the results and shows the ranking of cultivars according to yields in semolina or bran by projection on the axis 1

### Influence of Agronomical Factors on Milling Yields (% d.b.)

	Semolina (C/F)	Flour	Bran
● Nitrogen (-)	72.3 (8.8)	10.4	17.3
● Nitrogen (+)	75.6 (8.5)	7.5	16.9
● Water (-)	74.4 (7.7)	7.0	18.6
● Water (+)	75.1 (7.3)	7.0	17.9
● Year 1	74.1 (6.9)	7.8	18.2
● Year 2	74.7 (9.2)	8.1	17.2
<i>F (Location)</i>	****	****	****
<i>F (Year)</i>	*	****	n.s.

Considering now agronomical factors, it is easy to notice significant differences as a result of nitrogen deficiency **especially in flour percentage** and, at a lower degree, of water stress that increases bran percentage due to shrivelling. This can be summarised as follows :

## Effects of Agronomical Factors on Semolina Value

- Water stress conditions give rise to shrivelling and have a negative effect on semolina value by increasing the percentage of bran
- Low nitrogen conditions adversely affect structure and mechanical properties of endosperm resulting in a higher percentage of flour



1) Water stress conditions give rise to shrivelling and have a negative effect on semolina value by increasing the percentage of bran

2) In our experiment, low nitrogen conditions much more adversely affect structure and mechanical properties of endosperm resulting in a higher percentage of flour

## Semolina Value of Durum Wheats

- Large genetic variation of semolina yield
- Ratio endosperm/enveloppes is mainly cultivar-dependent
- Endosperm friability depends on cultivar and on growing condition (nitrogen nutrition)
- Milling behaviour is strongly influenced by harvest year and less by location and cultivar



In conclusion of my main part, I'd like to emphasize that, from a study at a pilot scale:

1) There is a large genetic variation of semolina yield.

In particular, cultivars with very small kernel (I mean intrinsically small, not shrivelled) yield significantly less semolina

2) Ratio endosperm/enveloppes is mainly cultivar-dependent

3) Endosperm friability depends both on cultivar and on growing condition (nitrogen nutrition)

4) Also, milling behaviour (especially coarse/fine ratio) is strongly influenced by harvest year and less by location and cultivar

5) On a technological point of view, cultivars with good semolina potential are those from which a high percentage of pure semolina can be extracted as soon as the first breaks

## Some Correlations between Grain Characteristics

- Grain weight is correlated to grain surface ( $r = 0.98$ ) and width ( $r = 0.97$ )
- Grain length shows little relation with the other size parameters
- Vitreousness is correlated to hardness (PSI:  $r = -0.87$  ; NIR:  $r = 0.88$ )
- Hardness measured on single kernel by SKCS indicates significant differences only from highly unvitreous samples



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- 4) Hardness measured on single kernel by SKCS (Single Kernel Characterisation System, Perten) indicates significant differences only from highly unvitreous samples

### Some Correlations of Grain Characteristics to Semolina Value

- Semolina yield (S) can be only assessed using several factors:

$$S = 0.13 \text{ TKW} + 0.66 \text{ VMapp} + 0.87 \text{ Prot} + 0.04 \text{ NIR}$$

- Flour yield (F) depends on grain hardness (PSI:  $r = 0.89$  ; NIR:  $r = -0.83$ )
- Bran percentage depends on grain size (surface:  $r = -0.80$ ) ; width: ( $r = -0.79$ )
- Ratio coarse bran/fine bran is associated to vitreousness indicating an effect of the endosperm texture on bran friability



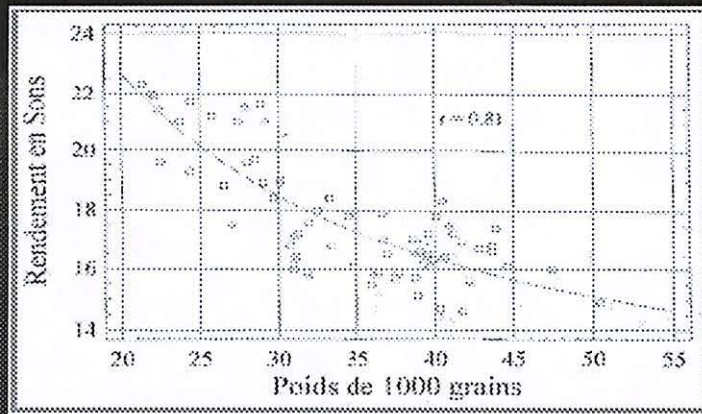
Additional comments can be made as follows:

- 1) Semolina yield (S) can be only assessed using several factors:

$$S = 0.13 \text{ TKW} + 0.66 \text{ VMapp} + 0.87 \text{ Prot} + 0.04 \text{ NIR}$$

- 2) It is confirmed that flour yield (F) depends on grain hardness (PSI:  $r = 0.89$  ; NIR:  $r = -0.83$ )
- 3) Bran percentage depends on grain size (surface:  $r = -0.80$ ) ; width: ( $r = -0.79$ )
- 4) Ratio coarse bran/fine bran is associated to vitreousness indicating an effect of the endosperm texture on bran friability

## Relationship Between 1000-Kernel-Weight and Bran Yield



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Another way to illustrate the main trends from whole results is the relationship between 1000-kernel-weight and bran yield.

This confirms that samples with TKW < 30 grams (left part of the curve) yield a significantly higher percentage of bran.

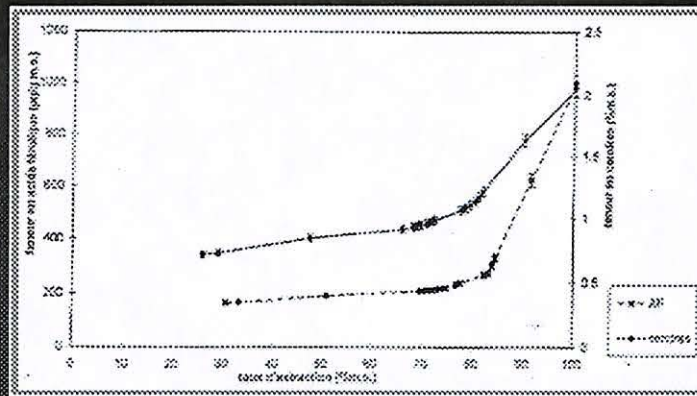


### Influence of Genetic and Agronomical Factors on Pentosans and Phenolic Acids

	Ash	Soluble Pentosans	Ferul. Acid	Di-F Acid	p-Coum. Acid
● Kernel					
Cultivar	****	****	****	****	****
Location	****	*	**	**	***
Year	****	n.s.	n.s.	**	n.s.
● Semolina					
Cultivar	***	***	**	n.s.	****
Location	***	**	n.s.	n.s.	n.s.
Year	**	n.s.	***	****	n.s.

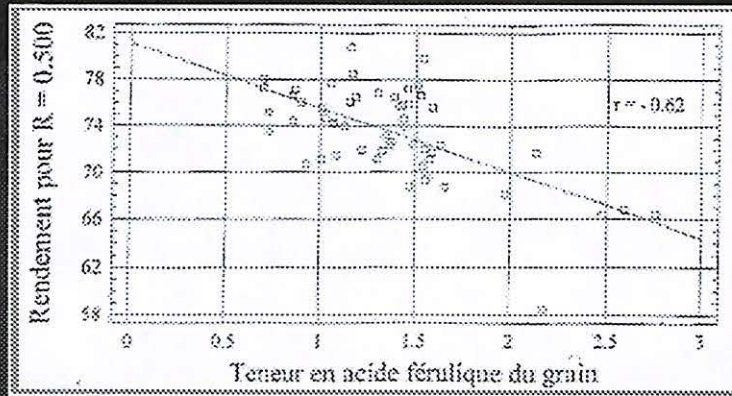
Last and very short part: we also investigated influence of genetic and agronomical factors on ash and on various cell-wall components such as soluble arabinoxylans, ferulic acid, di-ferulic acid, para-coumaric acid. Among these results, we can notice that all cell-wall components are very highly significantly influenced by cultivar, whereas ash is also highly significantly influenced by growing location and year.

## Comparison between Ash and Ferulic Acid Curves



This is a comparison between cumulated ash and ferulic acid curves. The shape of the ferulic acid curve (very flat gradient in the endosperm and very well marked angle at the level of the aleurone layer) demonstrates that ferulic acid is a much better marker of bran contamination than ash.

## Relationship Between Ferulic Acid Content and Semolina Purity



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## Purity of Mill Streams

- Ash content of semolinas depend on that of the processed wheats
- Harvest year, growing location and cultivar strongly influence ash content of wheats
- The "growing location" and "year" effects can be minimised by expressing the ratio (R) between ash content of semolina and that of the processed wheat
- Ferulic acid content could be useful as a marker of semolina purity



So, with regard to purity of mill streams, we found that:

- 1) Ash content of semolinas depend on that of the processed wheats
- 2) Harvest year, growing location and cultivar strongly influence ash content of wheats
- 3) The "growing location" and "year" effects can be minimised by expressing the ratio (R) between ash content of semolina and that of the processed wheat
- 4) Those cultivars giving the lowest yields in semolina for a constant R ratio (0.50) have kernels containing especially high content in ferulic acid
- 5) Ferulic acid content could be useful as a marker of semolina purity (in agreement with Hamer and Kelfkens' (TNO) studies on milling quality of bread wheats)

## Perspectives

- ✦ Development of a micro mill (100 g) instrumented with sensors to characterise milling behaviour of wheats
- ✦ Search of specific markers of separation between histological layers of wheat kernel
- ✦ Agronomical and genetic variation of ash content of kernel and endosperm
- ✦ Investigation of the various steps of grain formation (structure setting, filling, desiccation) on semolina value



Perspectives of this study can be given as follows:

- 1) Development of a micro mill (100 g) instrumented with sensors, that imitates a B1 break roll, to characterise milling behaviour of wheats
- 2) Search of specific markers of separation between histological layers of wheat kernel
- 3) Agronomical and genetic variation of ash content of kernel and endosperm
- 4) Investigation of the various steps of grain formation (structure setting, filling, desiccation) on semolina value