
Dry fractionation of wheat bran for the manufacture of functional ingredients

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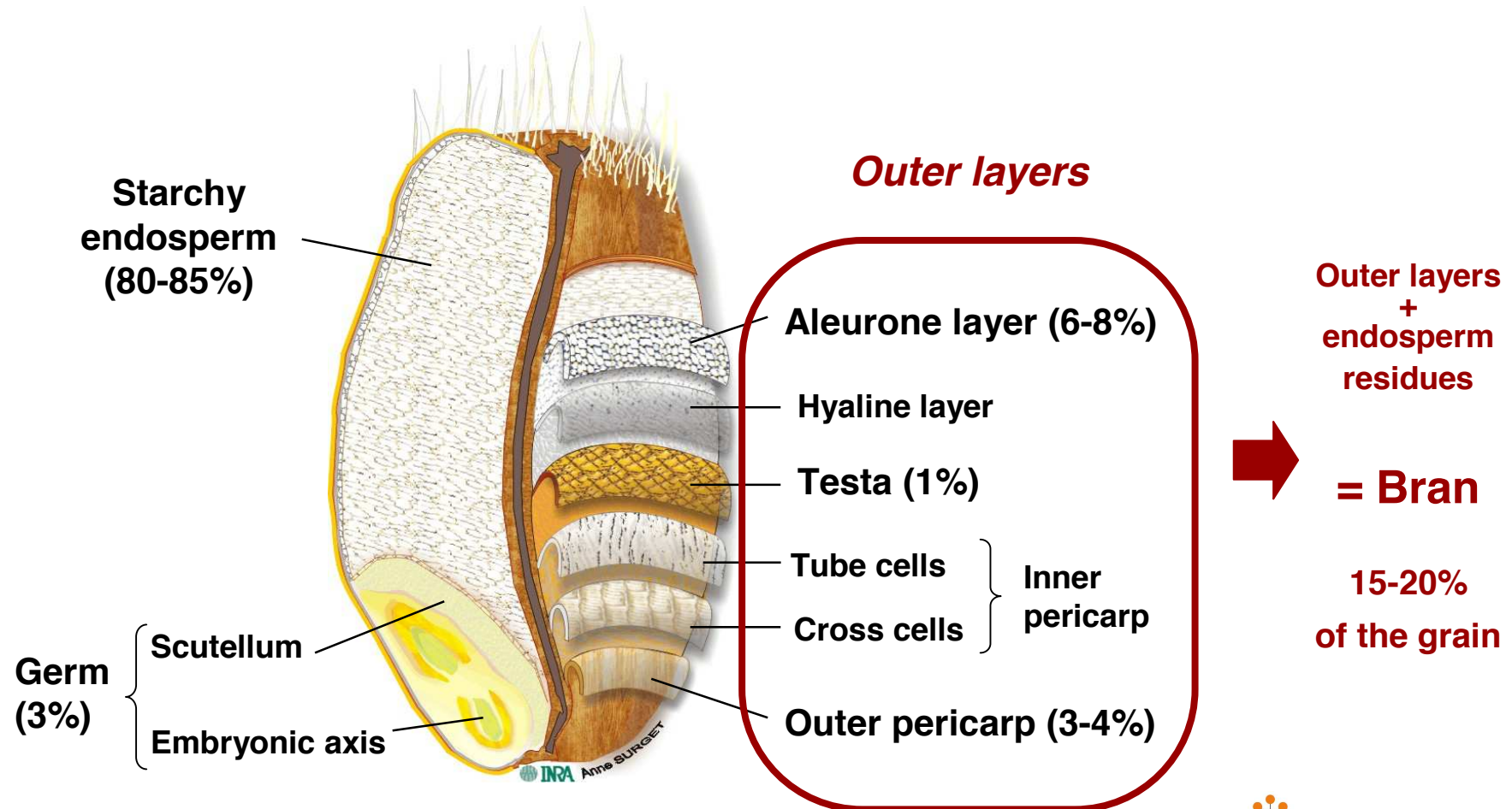


Introduction

Structure of the wheat grain

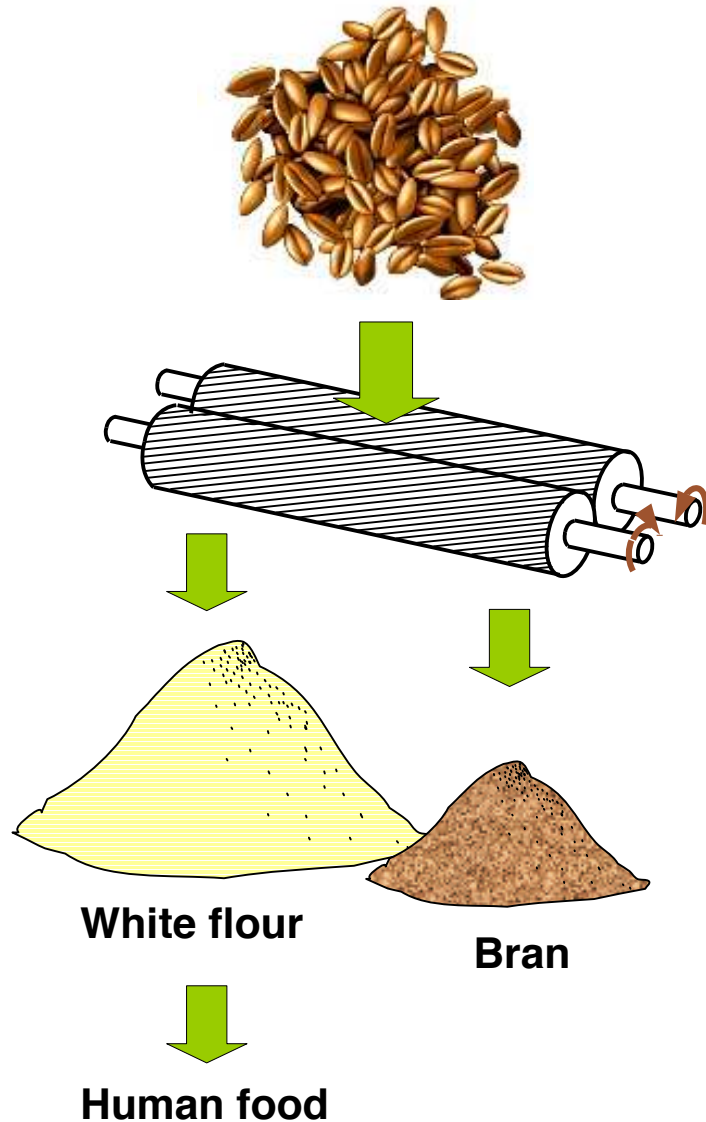
Wheat = the most consumed cereal in Europe, with 112 kg/person/year (FAO, 2003).

Wheat grain = complex structure, composed of several parts :



Introduction

Grain milling : production of wheat bran



Aim of the current milling process :

- *To separate the starchy endosperm from the wheat germ and the outer layers.*
- *Most of European cereal food products : made of refined white flour (endosperm).*

Wheat bran = important by-product :

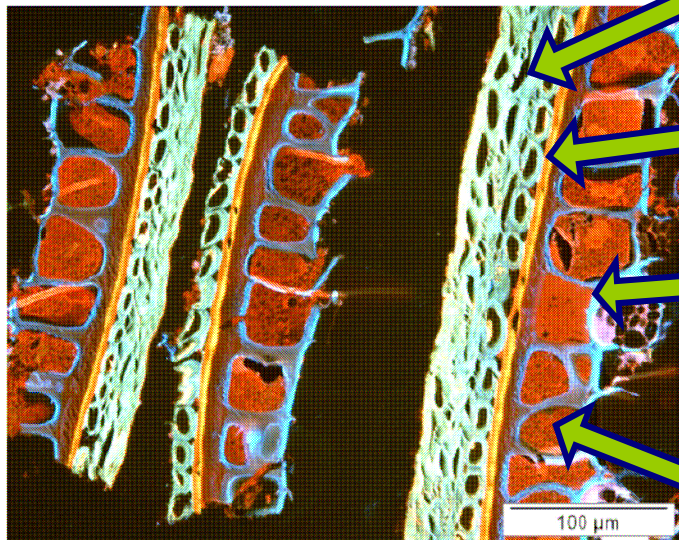
- *6 million tons produced / year in Europe*
- *Under-valued, mostly used for animal feeding*
- *But interesting nutritional potential*

Introduction

Structure and composition of wheat bran

Wheat bran :

- Contains most of the vitamins, minerals, antioxidants & interesting phytochemicals.
- Can contribute to increase the nutritional quality of foods, if included in flours during milling, or **used as food ingredients**.



Microscopy analyses : VTT-Finland

Pericarp :

- Insoluble dietary fibers
- Antioxidants bound to cell walls (phenolic acid oligomers)

Testa : Alkylresorcinols

Aleurone cell wall :

- Dietary fibers (arabinoxylans, β -glucans)
- Bound antioxidants (Ferulic acid monomers)

Intracellular contents (trapped in the cells):

- Proteins & lipids
- Antioxidants
- Vitamin E & B vitamins
- Minerals + Phytic acid

Fractionation of wheat bran : why ?

To remove detrimental compounds

- **Mycotoxins, heavy metals & pesticide residues, concentrated in the outer pericarp** (*Aureli and D'Egidio, 2007; Fleurat-Lessard et al., 2007; Laca et al., 2006*).
- **Phenolic compounds responsible for bitter taste** (*Heinio, 2008*).
- **Anti-nutritional factors like phytates, or other compounds that are detrimental for breadmaking (enzymes, thiols...)**

To concentrate interesting compounds

- **To produce ingredients enriched in aleurone, known for its high nutritional potential** (*Amrein, 2003; Bach Knudsen, 1995; Buri, 2004; Fenech, 1999*).
- **Or ingredients rich in dietary fibres and/or rich in antioxidant compounds.**



→ **To be used as “health-promoting” food ingredients**

Dry Fractionation :



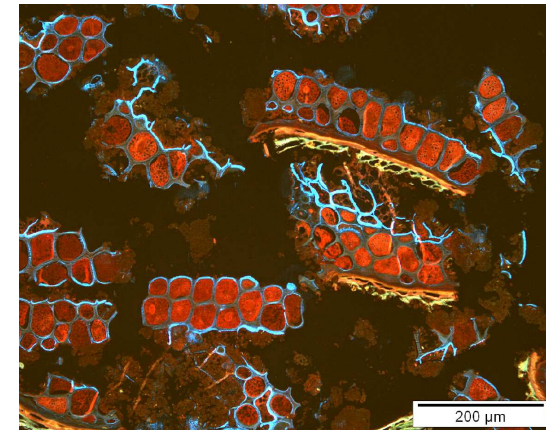
Combination of several processing steps : dissociation step + separation steps

- “green technology” : no harmful solvents, no effluents
- no drying steps, no denaturation of compounds, keeps matrix effect

Several processes already exist (patents)

focused on aleurone layer or aleurone cell purification :

- Stone & Minifie (1988) : separation of aleurone
- Goodman Fielder (1995) : aleurone rich flour
- Bühler (2003) : separation of aleurone cells
→ clusters of \pm intact cells



Processes based on :

- Traditional processes : grinding, sieving, air-classification
- Innovative processes : electrostatic separation, but with low yields ($\approx 5\%$)

Is it possible to fractionate more ?

from « histological fractionation » to « sub-cell fractionation »

Innovative processes for bran fractionation

Ultra-fine grinding of bran :

- Separation of cell walls / cell contents : more specific ingredients
- Increase of the bio-accessibility of the nutrients ?

Cryogenic grinding of bran :

- Widespread in drug industry and for spices processing
- A way to obtain very fine particles
- Allow the preservation of biological activities (no heating during processing)

Electrostatic separation :

- Good method for sorting powders
- Charging of the particles & separation of the particles in an electric field

1. Fragmentation / Dissociation

1st step of fractionation processes → tissues fragmentation & dissociation

Cryogenic grinding : very low T° → study of mechanical properties at low T°

Mechanical properties of the different isolated bran layers :

- *Tensile tests at various temperatures (-100 to 25°C)*
- *On whole outer layers*

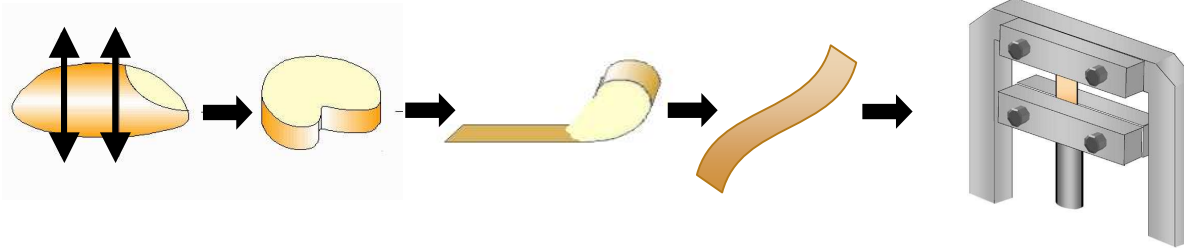
Grinding tests of bran at pilot scale :

- *Influence of the composition of bran layers*
- *Influence of the grinding temperature*

1. Fragmentation / Dissociation

Mechanical properties

Manual dissection of wheat grains

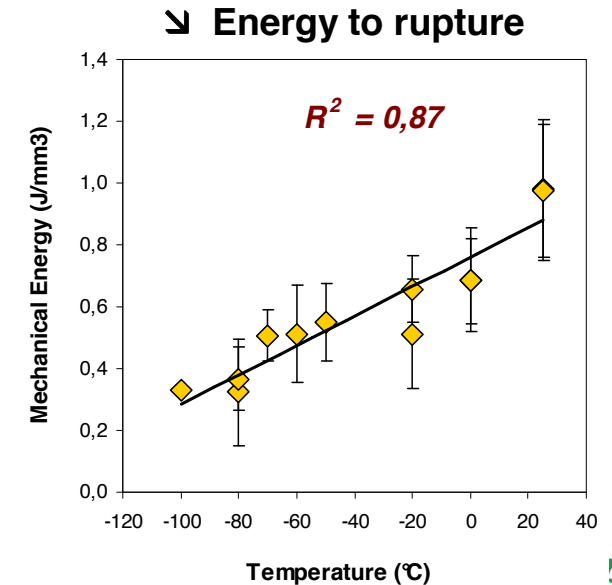
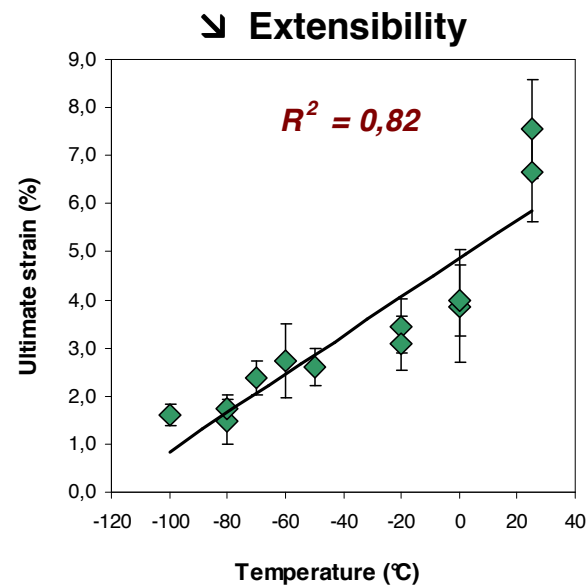
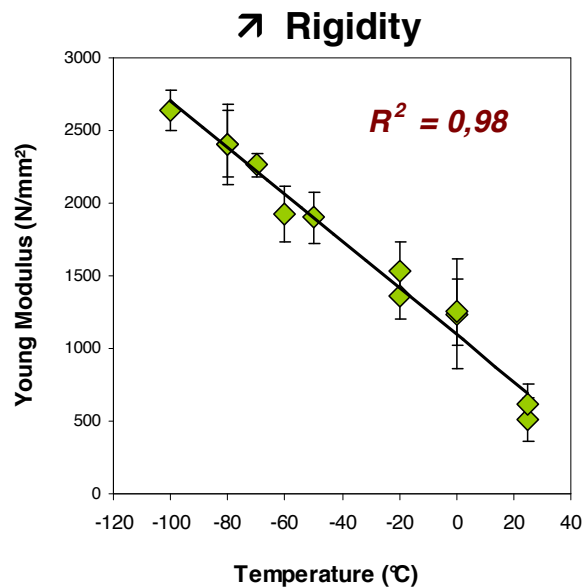


Tensile tests at controlled T°

Mechanical properties of whole bran layers

↘ T° : greatly influences the mechanical properties of whole bran layers

- Increase in rigidity, Decrease in extensibility
- Loss of plasticity (ductile → brittle) & mechanical energy to rupture.

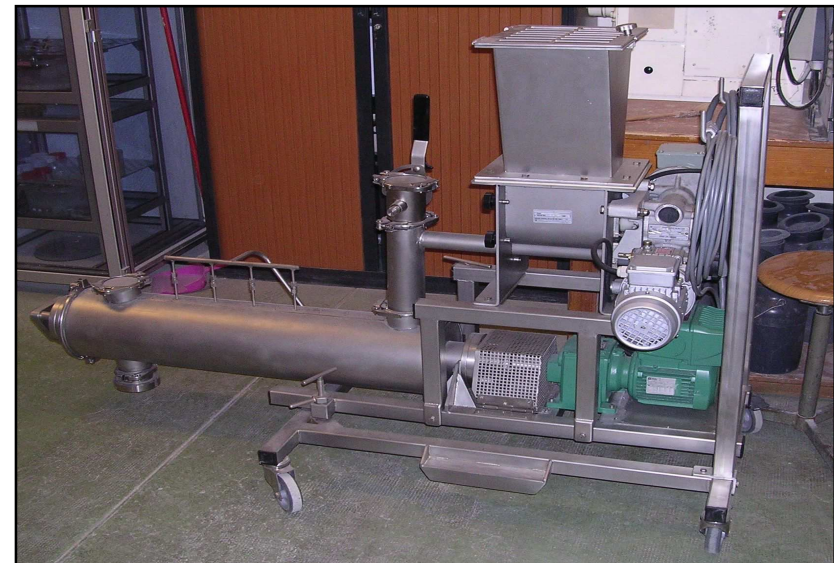
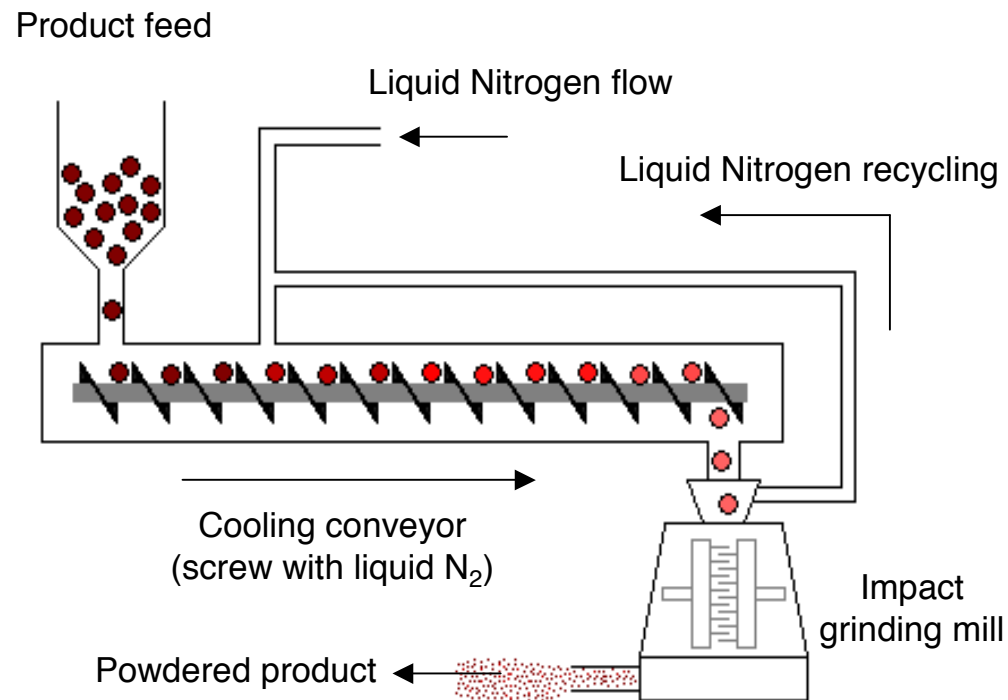


1. Fragmentation / Dissociation

Process : ultrafine grinding

Ultrafine grinding of bran : influence of the temperature

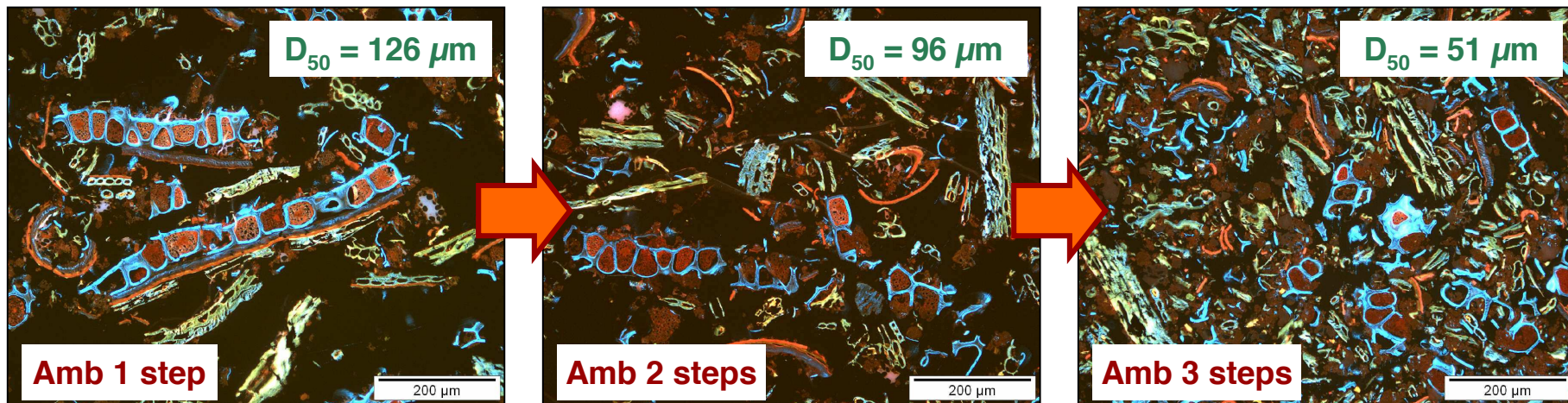
- At pilot scale : on several kg using a high speed impact mill with a screw feeder
- Grinding at ambient temperature and under cryogenic conditions (liquid nitrogen).
- Particles' characterization : particle's size & microscopy.



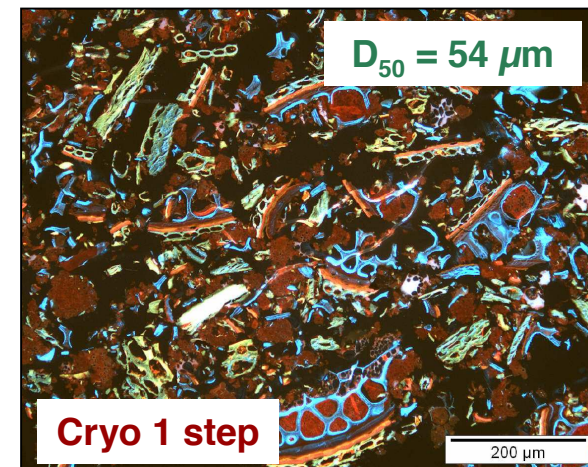
1. Fragmentation / Dissociation

Bran grinding at pilot scale

Influence of the temperature on the fragmentation & dissociation of bran



- Ultrafine grinding amb & cryo : same D_{50} but \neq dissociation.
- Successive grinding steps at ambient T° \rightarrow dissociation of the different bran tissues (different tissues extensibilities).
- Cryogenic grinding: low temperature = \nearrow brittleness and \searrow extensibility of all the tissues \rightarrow composite particles.



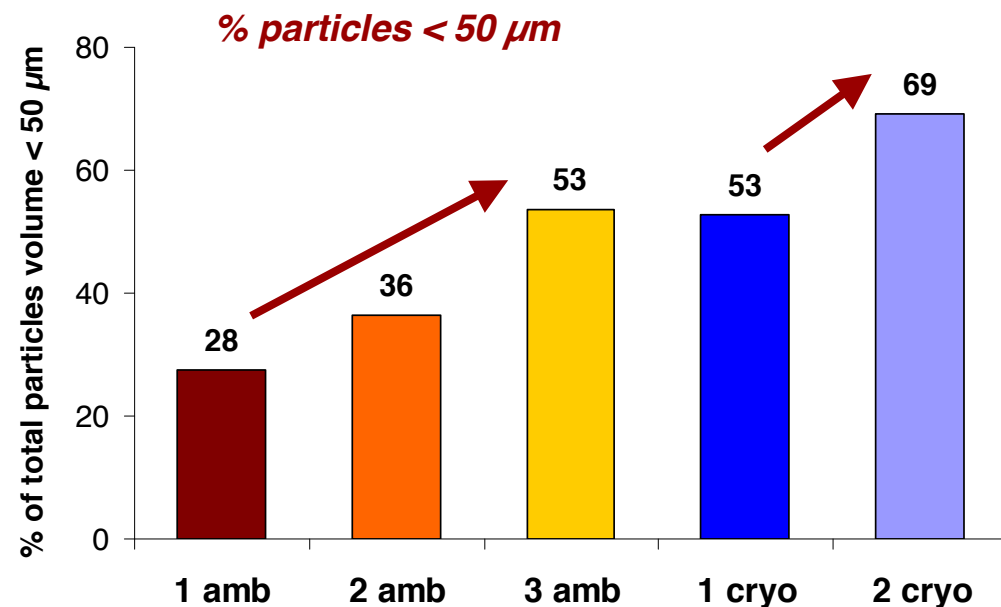
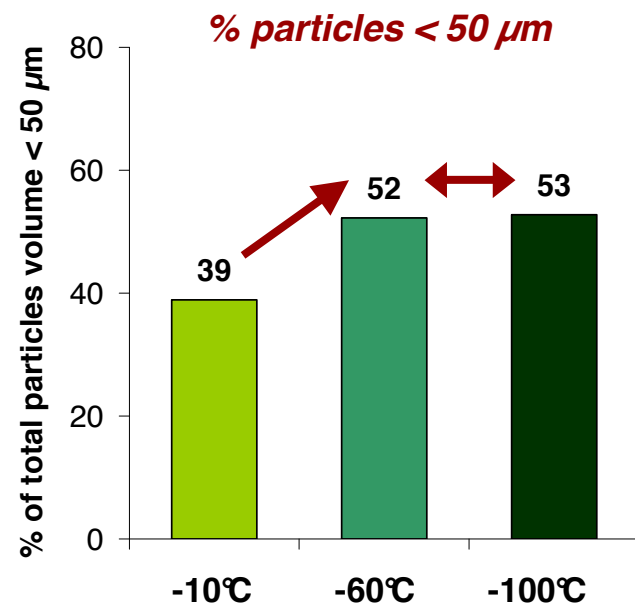
Microscopy : VTT-Finland

1. Fragmentation / Dissociation

Bran grinding at pilot scale

Influence of the temperature on the fragmentation & dissociation of bran

- Cryogenic grinding : most important changes in particle size reduction between -10°C and -60°C.
- Cryogenic grinding : low T° \nearrow bran brittleness \rightarrow faster particles size reduction.
2 cryogenic grinding steps \nearrow proportion of fine particles.



2. Particles separation

2nd step of fractionation processes → sorting of the dissociated particles

The conventional separation methods (sieving, air-classification) are not adapted to the separation of ultrafine particles : inefficiency and re-agglomeration phenomena

→ Use of electrostatic separation, based on the particles' ability to get charged

Study of the electrostatic properties of particles, at small scale :

- *Tribo-charging of different bran materials*

Study of the separation after tribo-charging at pilot scale :

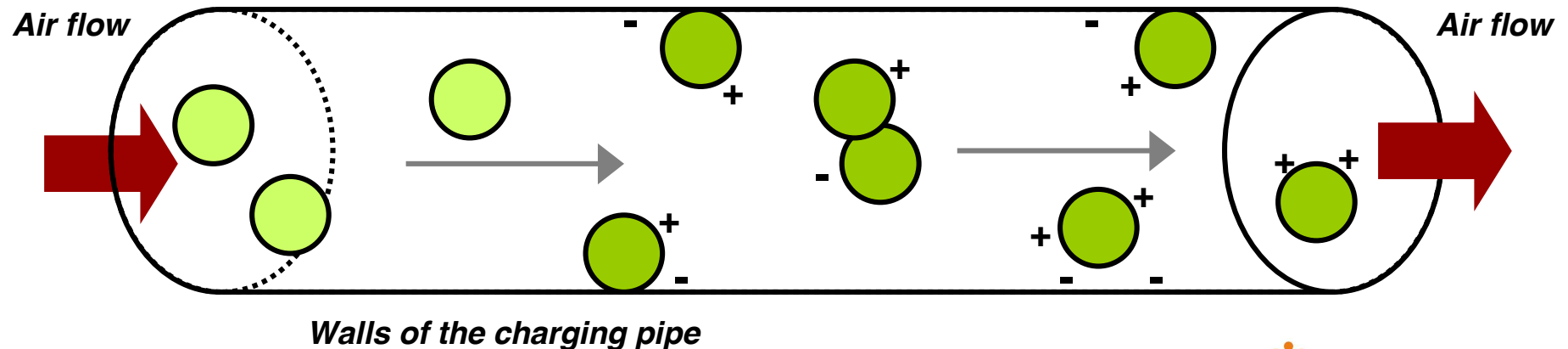
- *Influence of the composition of particles*

2. Particles separation

Electrostatic properties of materials

Tribo-charging of particles : definition

- Particles charged by rubbing against each other & the charging device walls.
- Materials : electron donor / electron acceptor → Behavior highly influenced by the surface properties of the particles (composition, water content).
- The particles are then separated depending on the sign of their acquired charge.

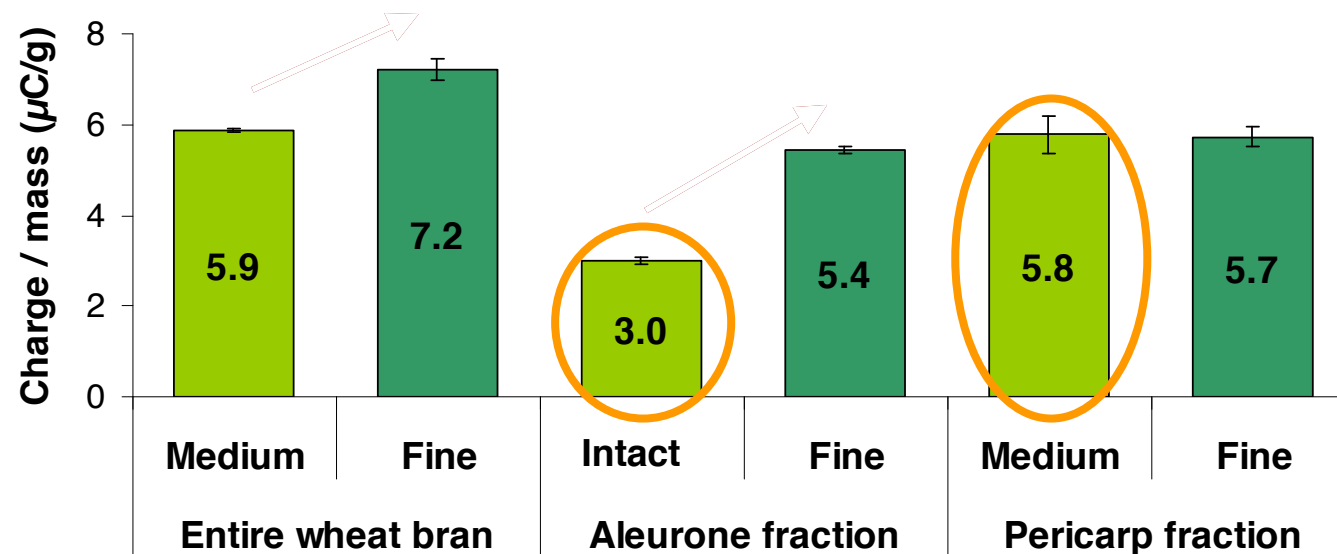


2. Particles separation

Electrostatic properties of materials

Tribo-charging of particles

- Intact aleurone cells & pericarp particles display different tribo-charging behavior → due to differences in cell walls compositions.
- The particles of these materials may be separated by electrostatic separation.
- Effect of the breakage of aleurone cells during grinding : the release of intracellular compounds modifies the particles surface composition → modifies the charging behavior of the aleurone and bran particles .

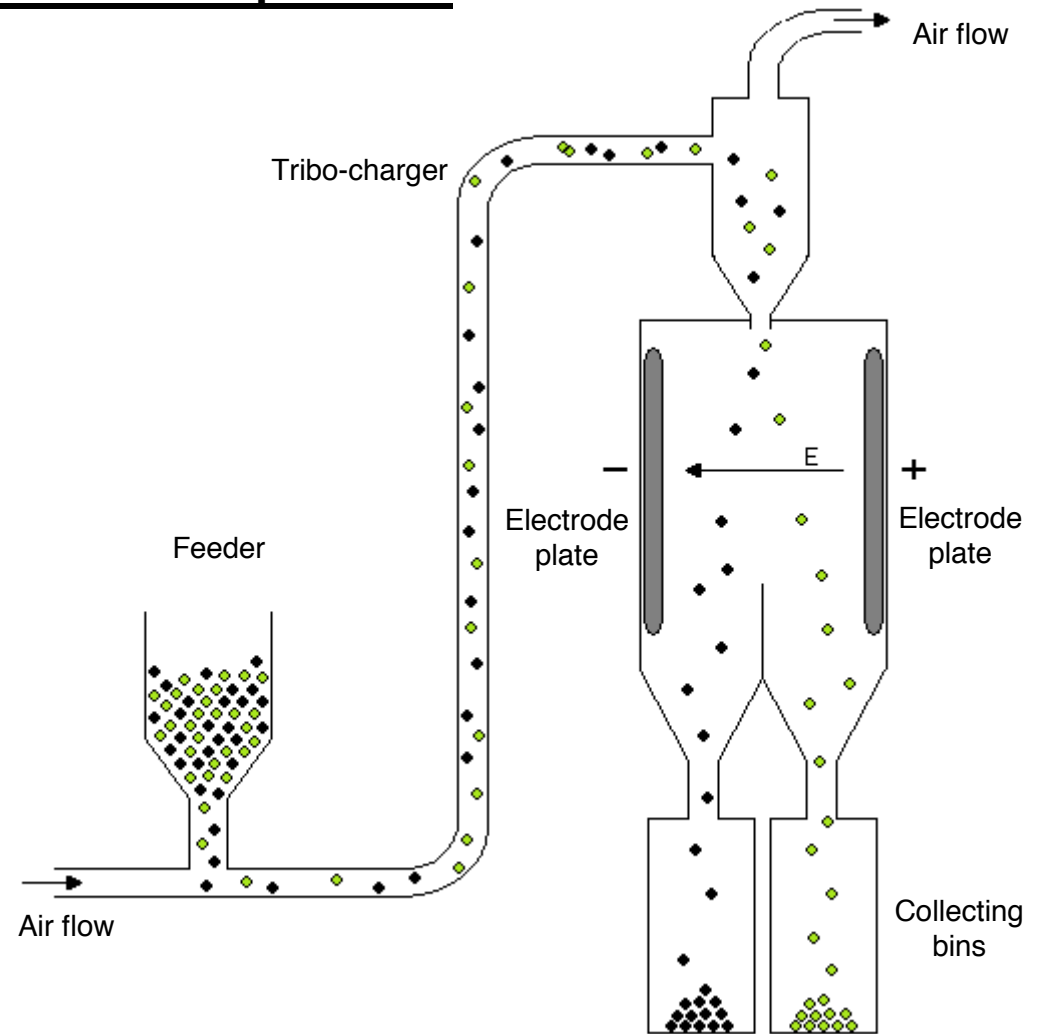


2. Particles separation

Electrostatic separation at pilot scale

Use of tribo-charging for the separation of bran particles

- Electrostatic separation **tested at pilot scale**, after tribo-charging.
- Particles separated in an electric field, depending on their acquired charges.
- The dissociation of the different bran layers = important parameter
- High % of composite particles in bran : much lower purity of fractions.
- 3 successive separation steps.
Starting material : ultrafine ground bran ($D_{50} \approx 50 \mu\text{m}$).

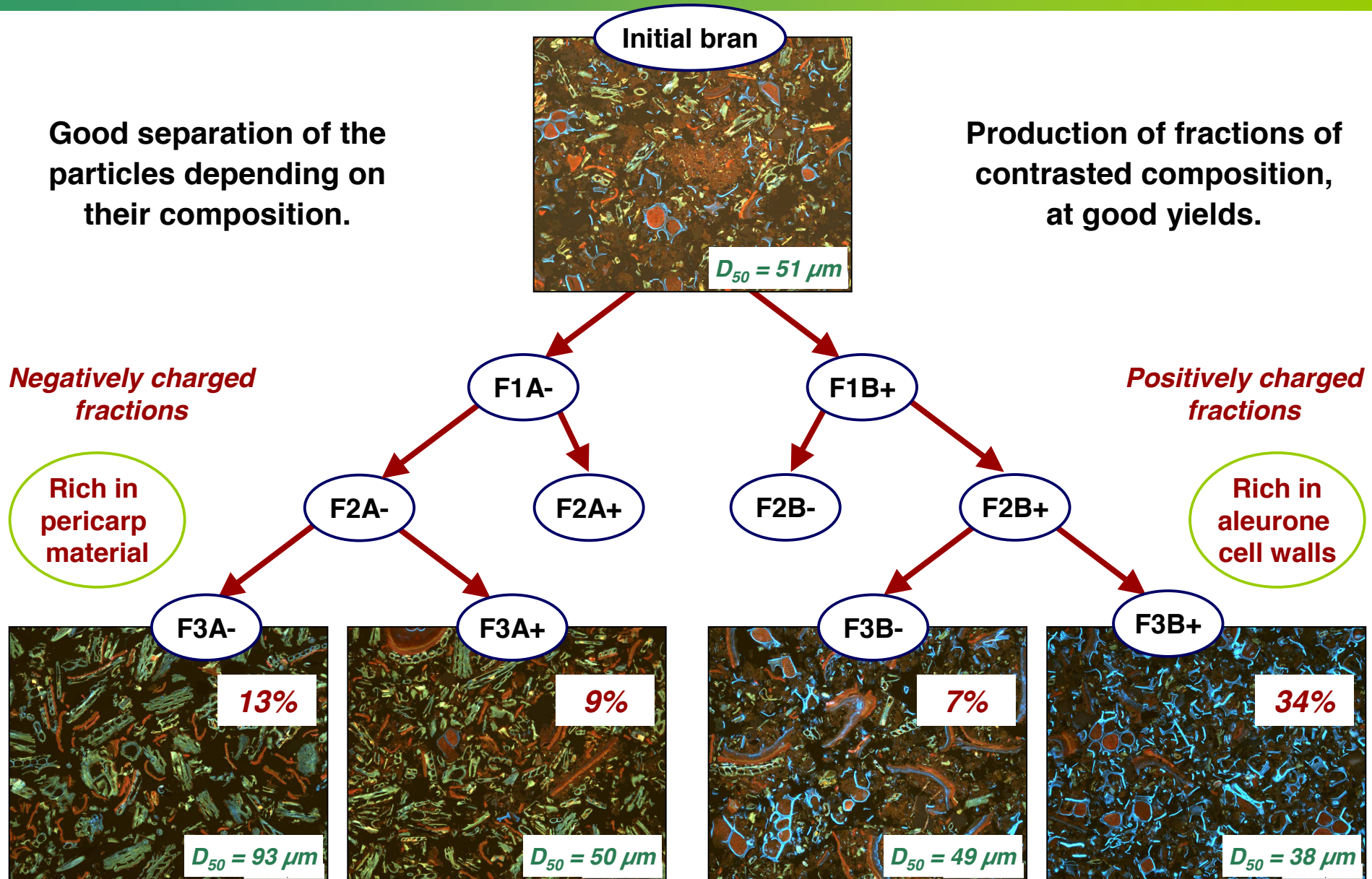


2. Particles separation

Electrostatic separation at pilot scale

Good separation of the particles depending on their composition.

Production of fractions of contrasted composition, at good yields.



Microscopy analyses : VTT-Finland

2. Particles separation

Electrostatic separation at pilot scale

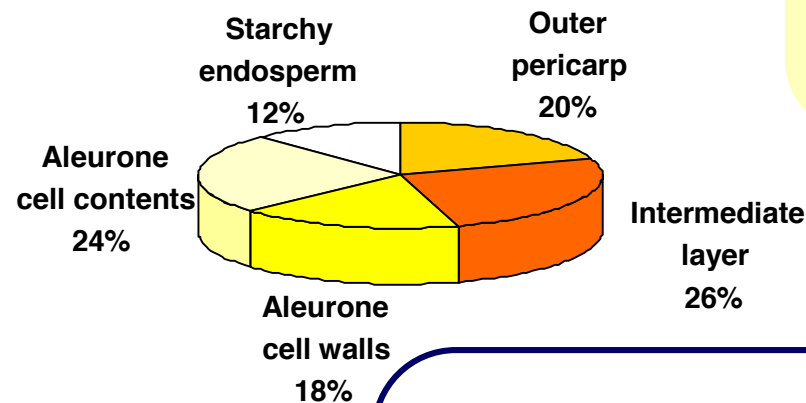
Production of fractions of contrasted composition, with good yields

Yield : 1/3 of the initial bran

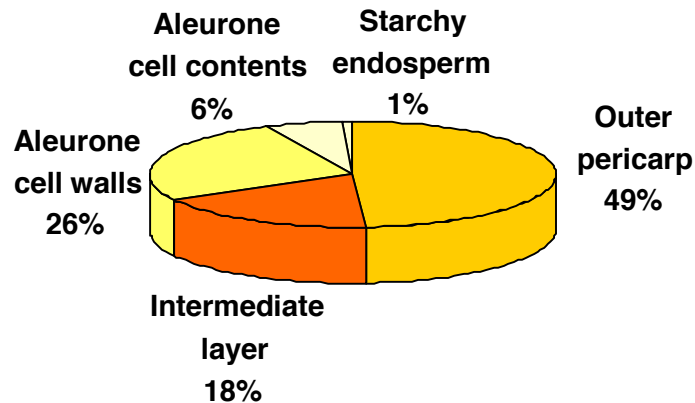
Composed at 1/3 of aleurone cell walls material

Contains (of the initial bran)
 2/3 aleurone cell walls
 2/3 p-coumaric acid
 2/3 ferulic acid

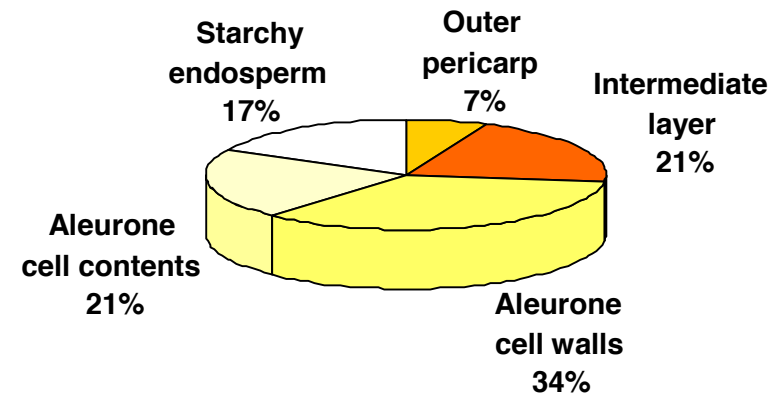
Initial ground bran



Pericarp typology



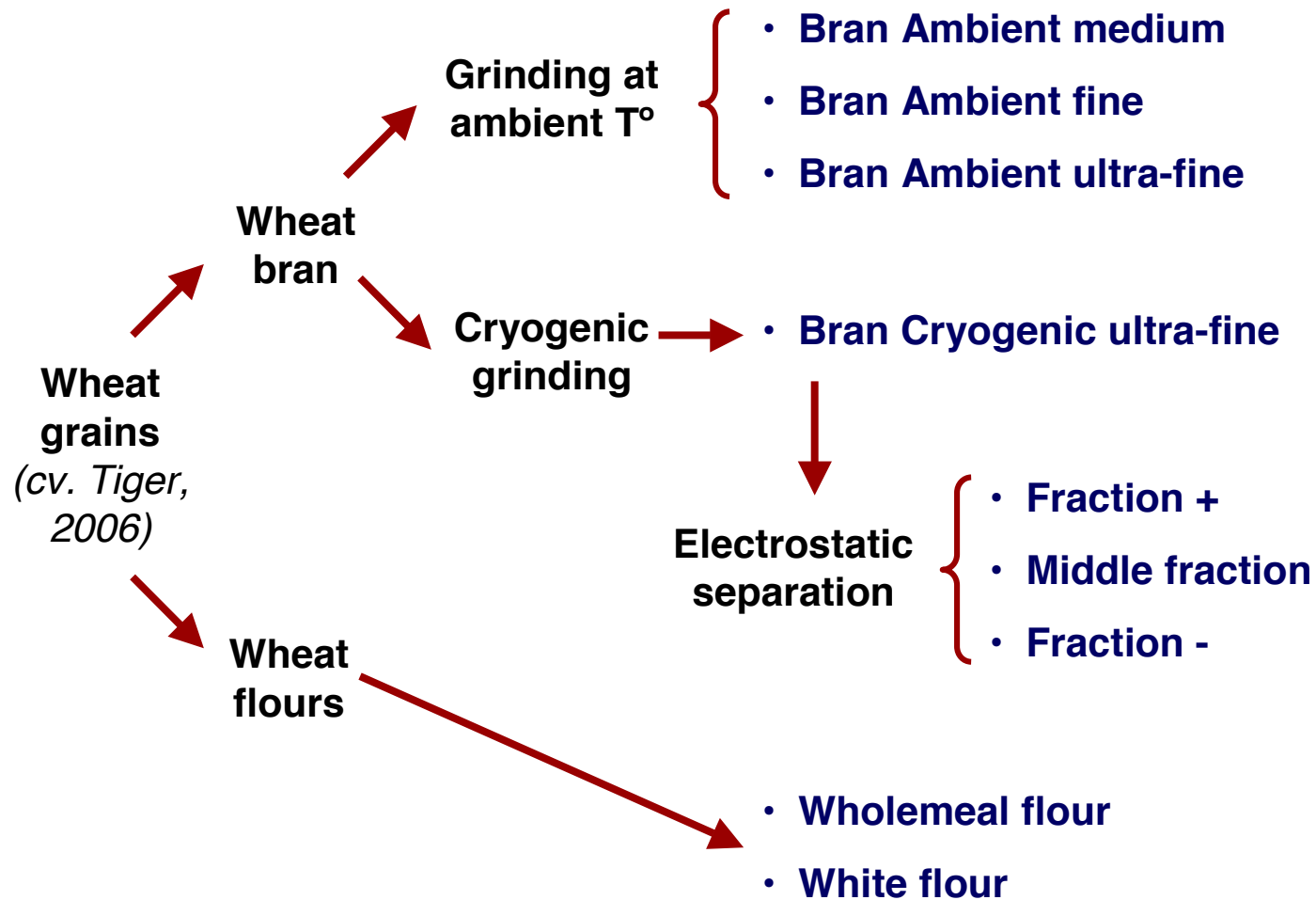
Aleurone typology



3. Properties of the fractions

Breadmaking tests

Production of wheat fractions & breads



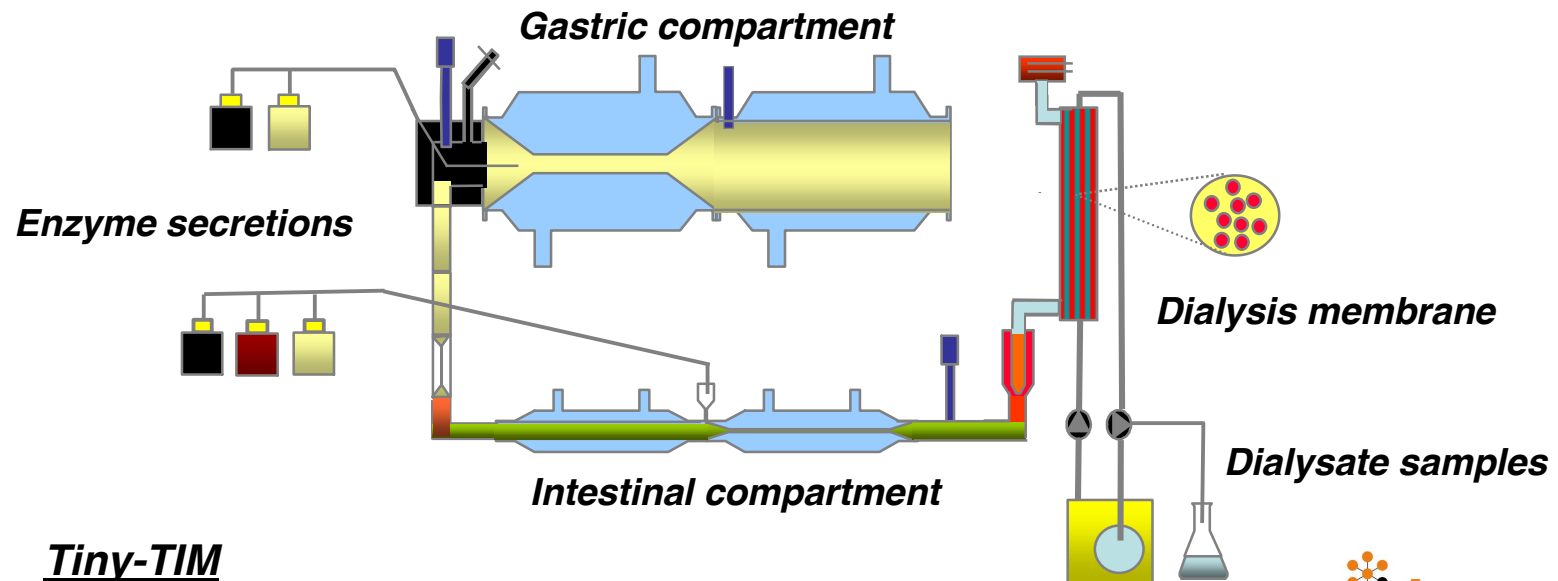
- white bread
- whole bread
- bran breads = whole bread, same ferulic acid and ash content

3. Properties of the fractions

Bioaccessibility of bioactives

Nutritional potential of bran fractions : *in vitro* digestions

- 30g of fresh bread → Tiny-TIM digestion (TNO Intestinal Model, NL), during 6 hours.
- Stomach + small intestine compartments.
- Controlled pH, T°, enzyme secretions & peristaltic movements.
- Dialysate samples (= contain all the bioaccessible compounds) collected every hour.
- Phenolic acids quantification.



3. Properties of the fractions

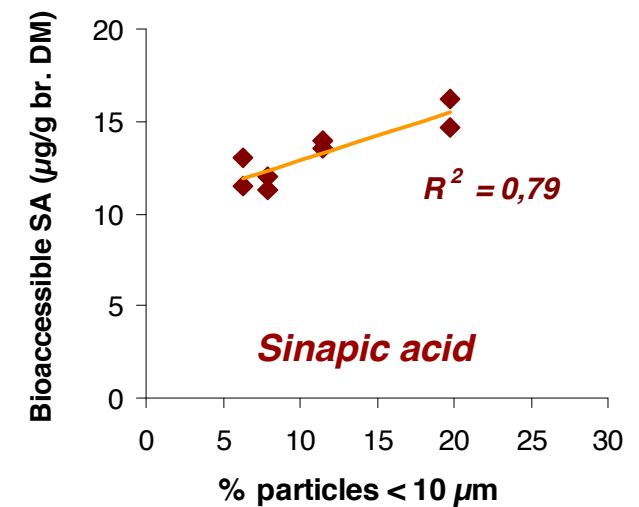
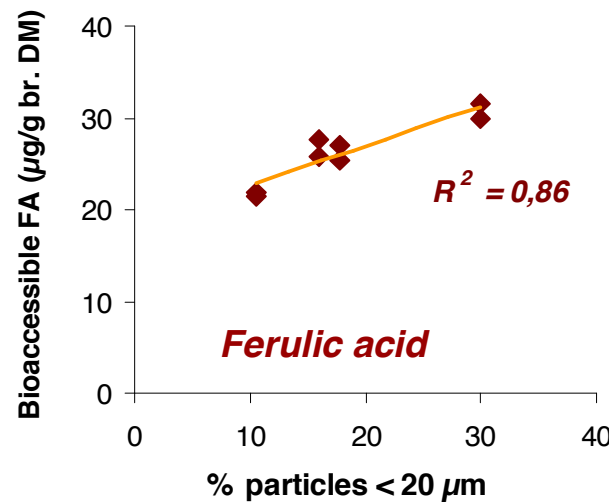
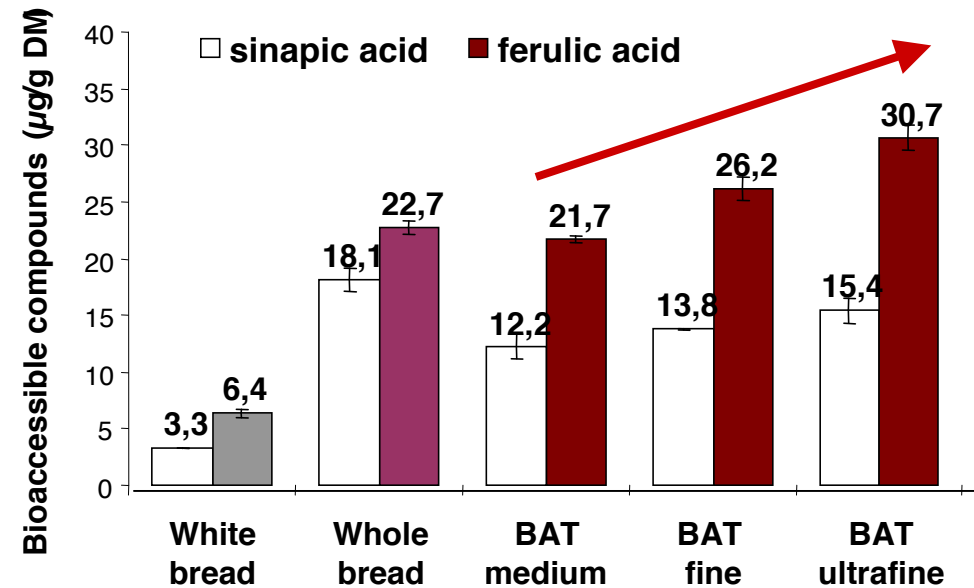
Bioaccessibility of bioactives

In bran-rich breads :

The bioaccessibility of phenolic acids depends on bran particle size

Breads made with ground bran fractions (coll M. Noort team, TNO, NL)

TIM experiments with bran breads (coll R. Havenaar team, TNO, NL)



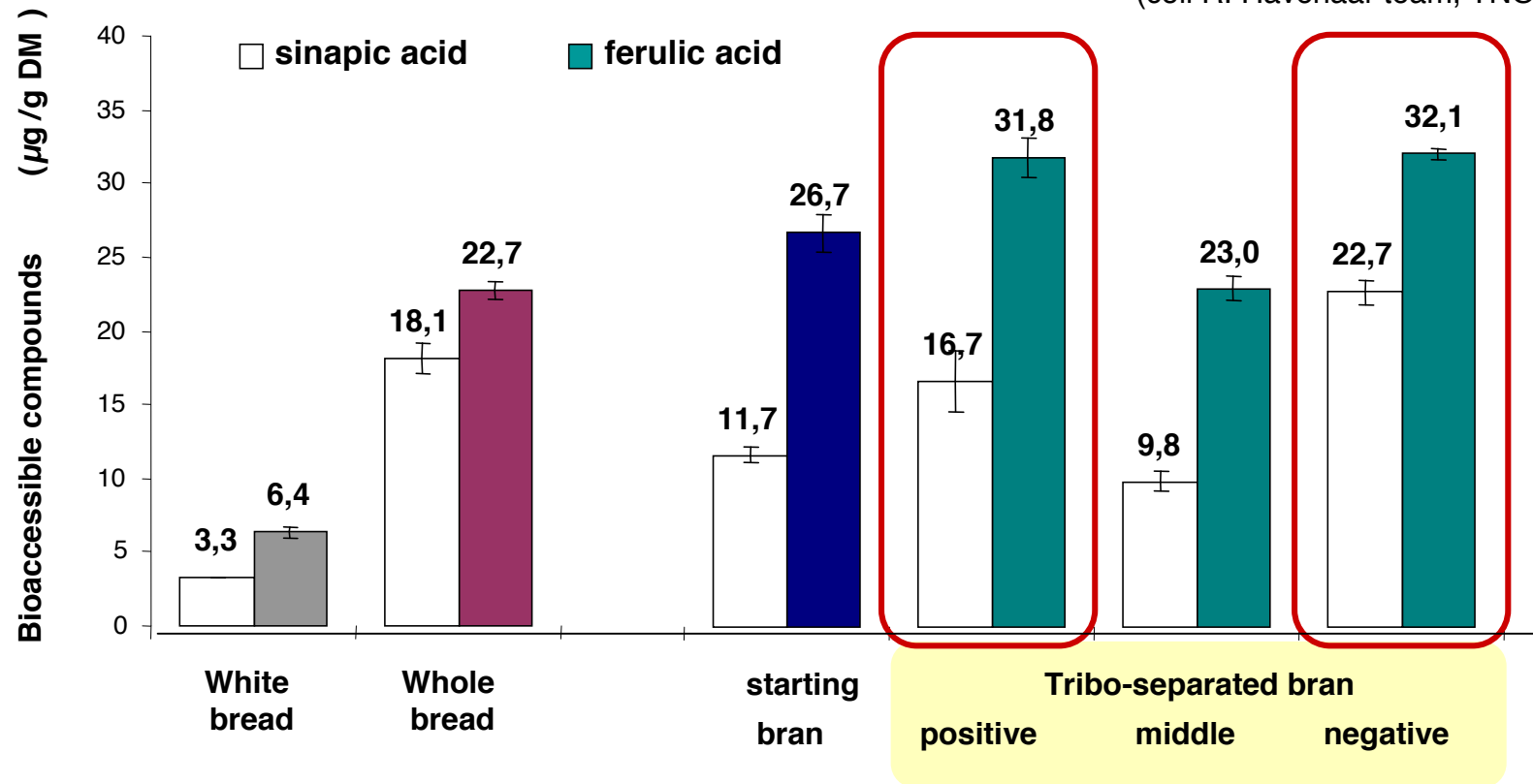
3. Properties of the fractions

Bioaccessibility of bioactives

The bioaccessibility of phenolic acids depends on the composition of fractions

Breads made with ground bran fractions (coll M. Noort team TNO, NL)

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Conclusion

- **Possible to produce food ingredients from bran by dry processing**
- **Possible to improve the bioaccessibility of important compounds**
 - in reducing the particle size
 - in selecting the tissues and sub-structure of interest
- **Question : the techno-functional impact of the peripheral layers of the grain**
 - more work is needed to fully understand and overcome the problem
- **Need to evaluate the investment and energy costs of innovative processes**
→ **transfert to industry**

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