

Effect of moisture and water activity on textural properties of toasted food products

Paola Pittia and Giampiero Sacchetti

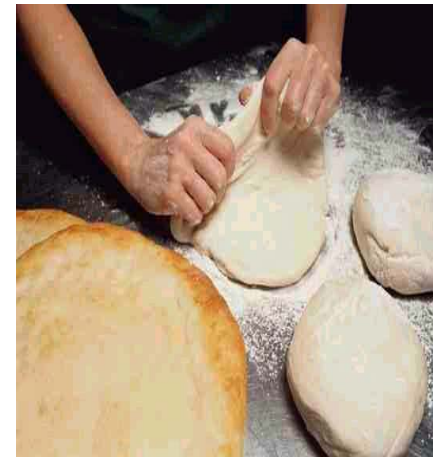
*Dipartimento di Scienze degli Alimenti
University of Teramo
Italy*



Euro Food's Water 27-28 March 2006, Bruxelles

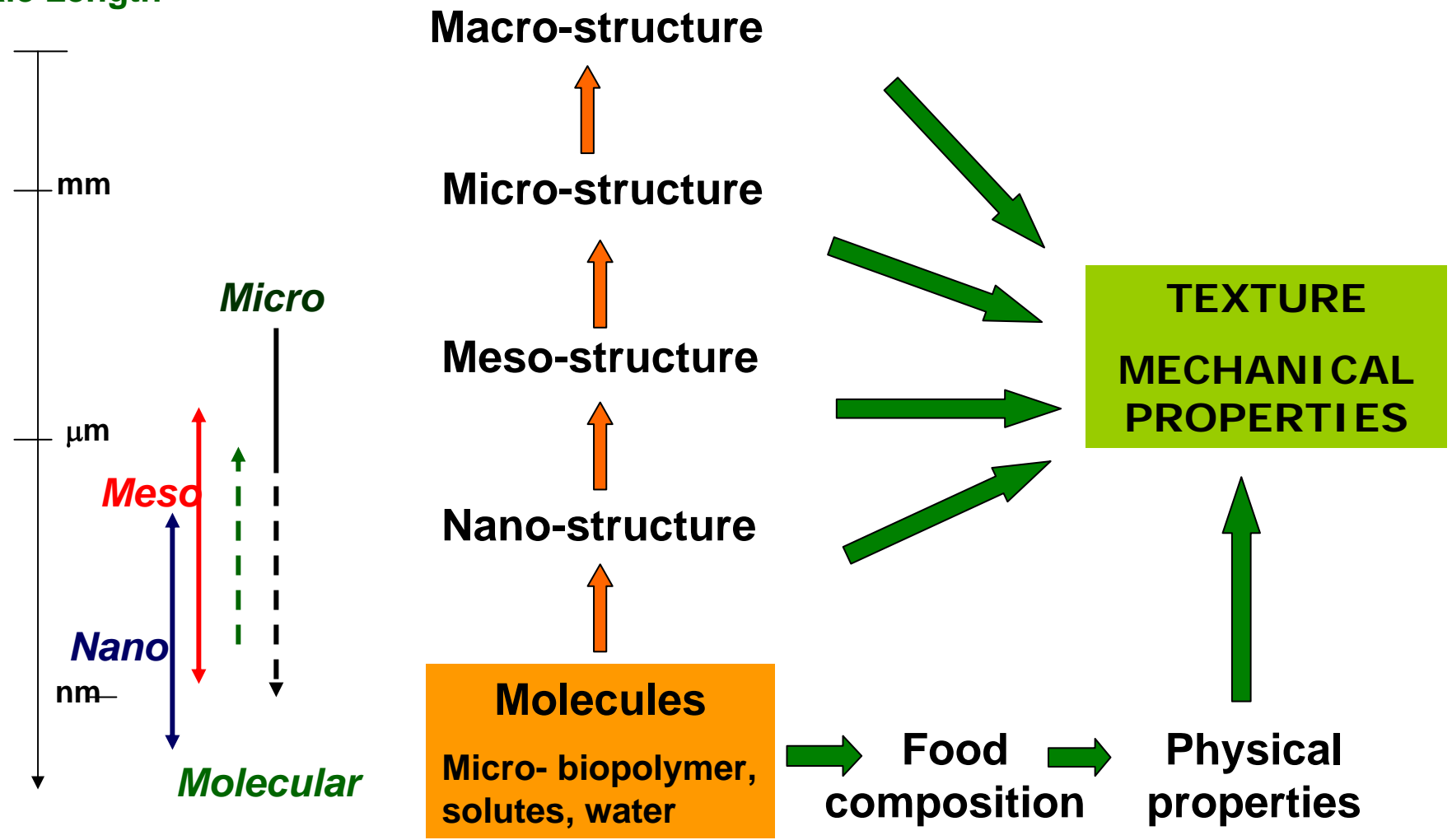
Texture

It comprises all physical characteristics sensed by the feeling of touch that are related to deformation under an applied force and measured objectively in terms of force, distance and time



Levels of structure and mechanical properties of food matrices

Scale Length



PP1 Textural properties of food matrices depends on many chemical and physical properties.

Composition (macromolecular components) presence and concentration of water.

Physical properties related to structure

Nowhere is the role of structure more apparent than in its effects on mechanical properties of foods and by extension on texture.

Foods having similar composition could exert a different mechanical behaviour depending on its structure

Paola Pittia, 17/03/2006

Structural properties of foods

Structure:

- NATIVE
- BY FORMULATION
- PROCESSING- INDUCED



PP2

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Mechanical properties in cellular structures

Role of:

cell geometry

cell size and distribution

cell wall thickness and strenght

porosity

PP4

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Roasting in food processing

Intense heat treatment at high temperature (160-260 °C) for a certain time able to induce significant changes on:

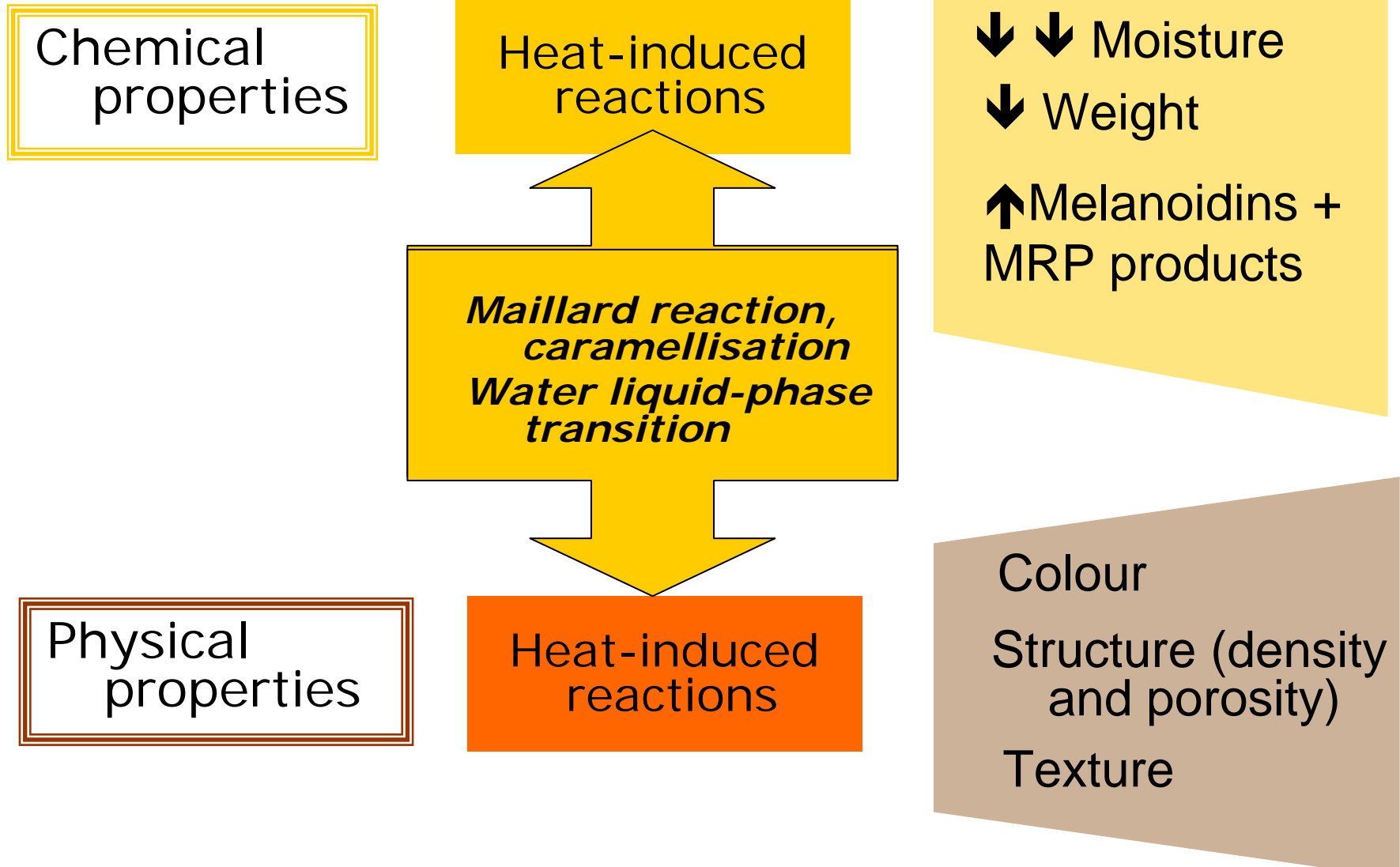
- chemical
- physical
- structural properties of food matrices

aimed to:

- ❖ increase edibility and/or improve nutritional value
- ❖ determine desired sensorial properties of foods (aroma, flavour, brittleness, crispiness, crunchiness,

Applications: coffee, malt, breakfast cereals, ...

Coffee roasting



Roasting in coffee processing

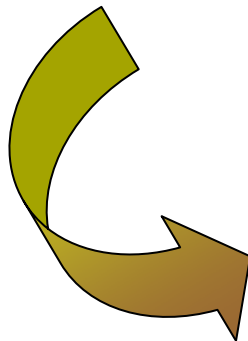
Raw bean

Moisture: 12%, aw: 0.5-0.6

Dense structure

Hard to fracture

“green” aroma



Roasted bean

0,1-0,5 % moisture

***Light-to-dark* brown colour**

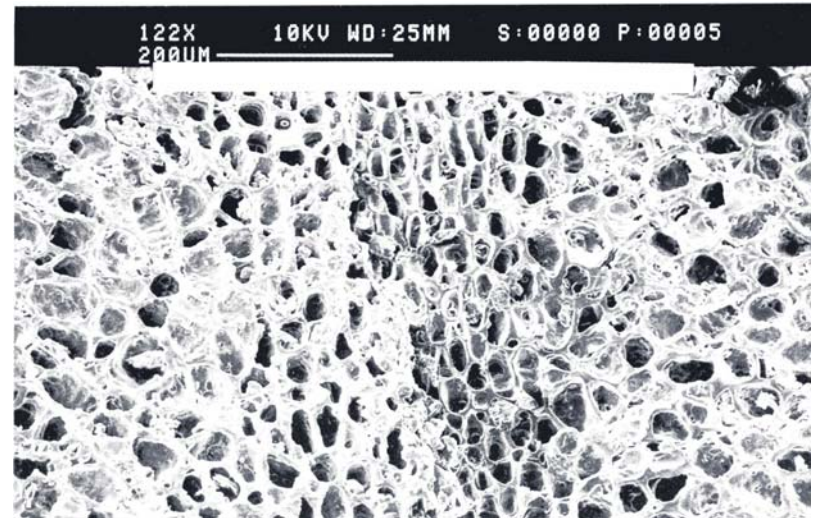
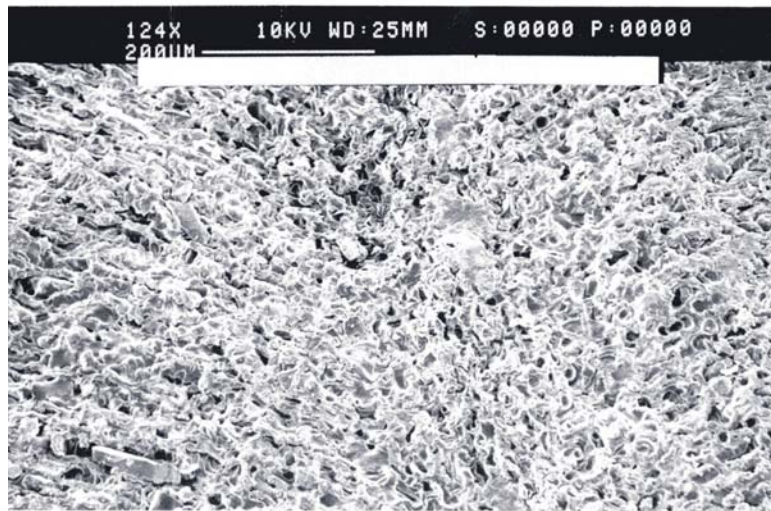
Characteristic aroma

Porose structure

Brittle, fragile

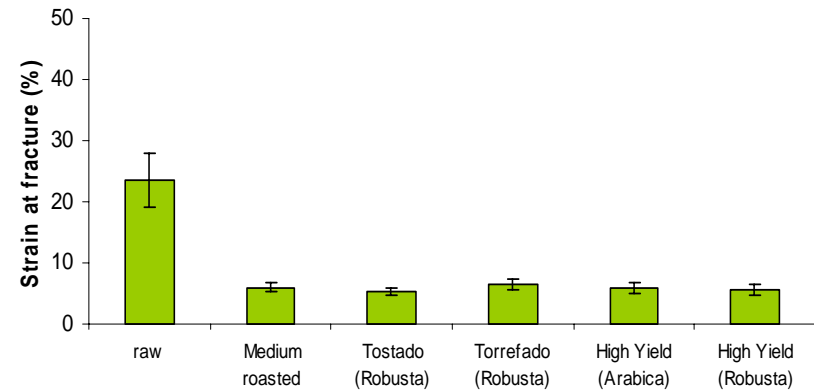
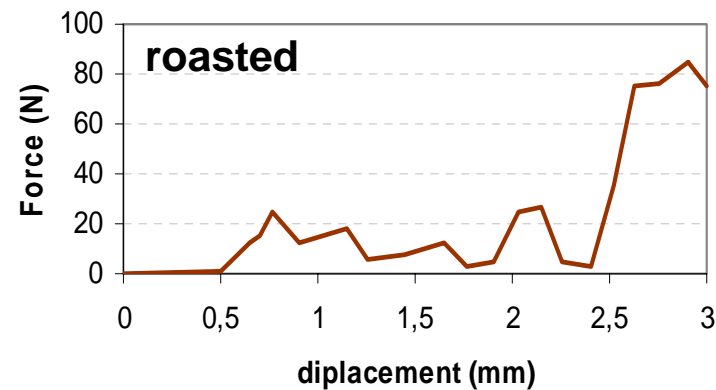
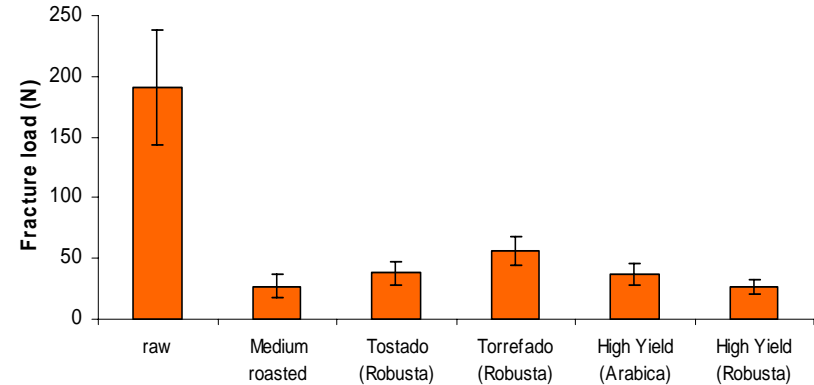
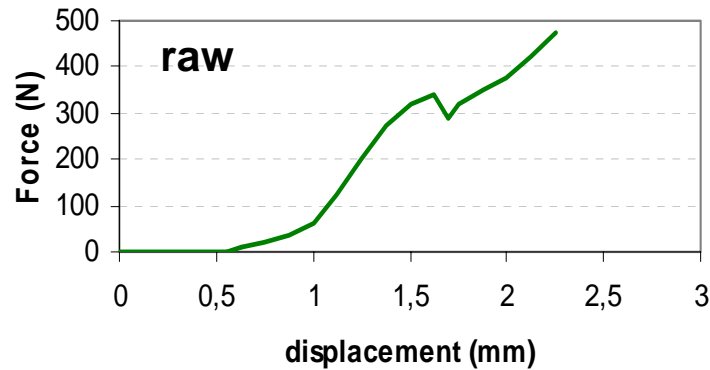


Structure of a cut section of raw and roasted coffee bean



Structure of a cut section of a green coffee bean (left) and roasted 10 min (right) (124 x, 10kV, WD: 25 mm) (Massini et al., 1991)

Roasting and textural properties



(Pittia et al., 1999; Pittia, 2005, unpublished data)

Roasted products and moisture adsorption: effects

Product-related



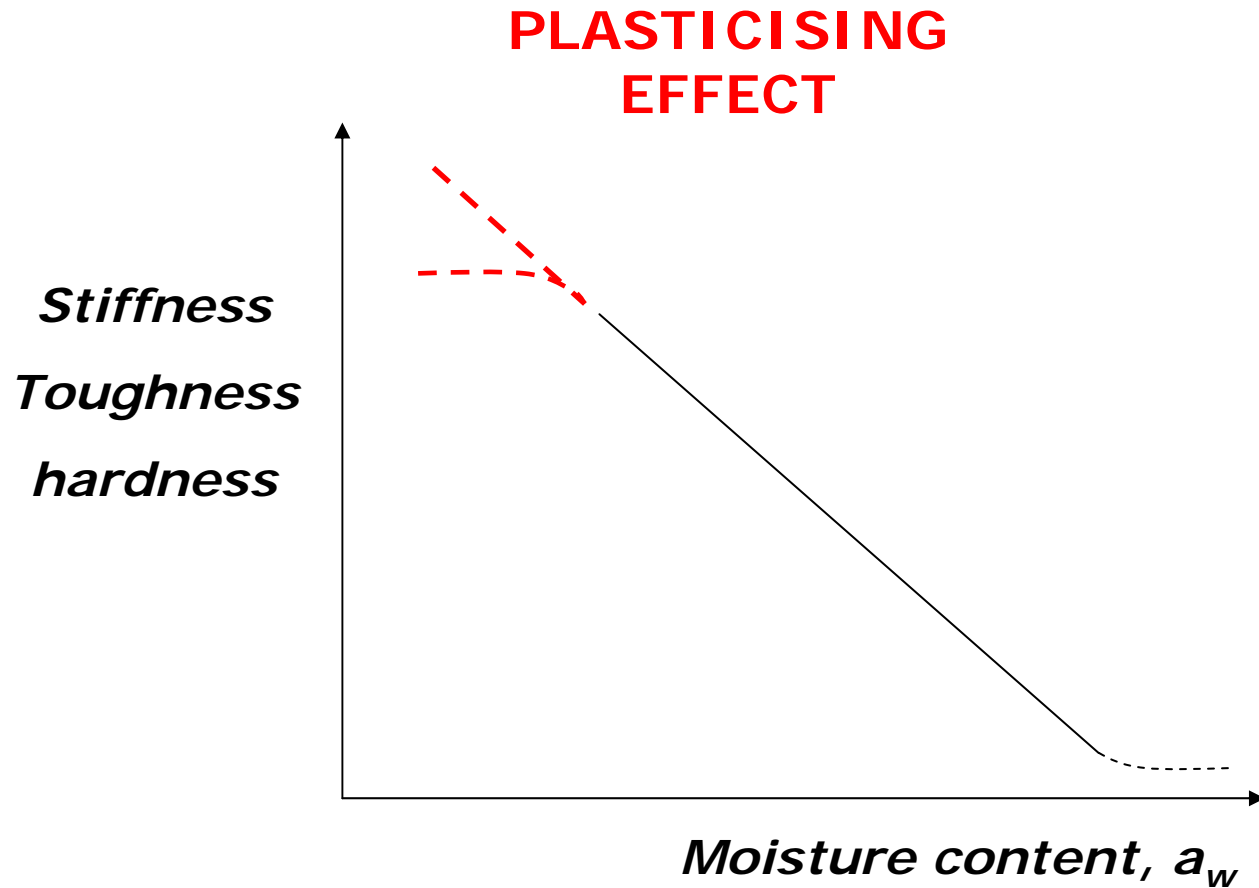
- Sensory quality and acceptability**
- Shelf-life**

Process-related



- Handling**
- Size reduction, grinding**
- Development of food products**

Water and mechanical properties

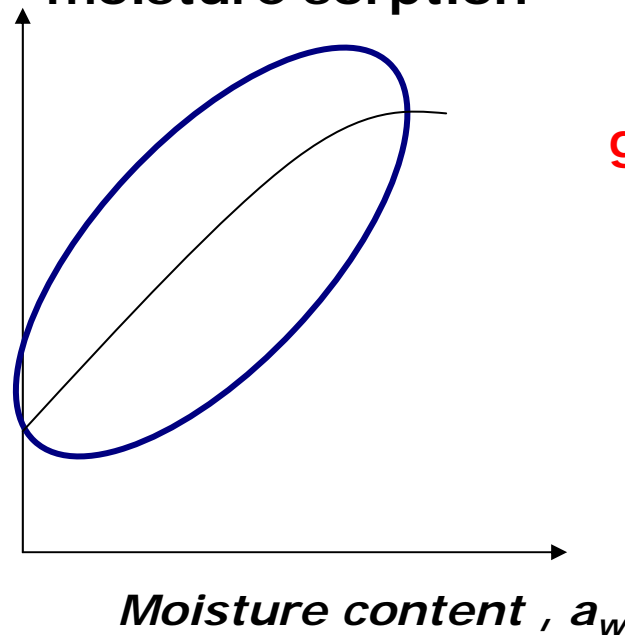


Water and mechanical properties

ANTIPLASTICISING EFFECT

increased stiffness, toughness, stress at failure, ... upon moisture sorption

Stiffness
Toughness
hardness

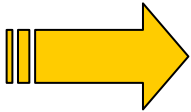


glassy, amorphous
matrices



Cereal snacks, gluten films, meat proteins

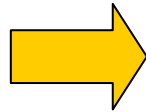
ANTI-PLASTICISING EFFECT



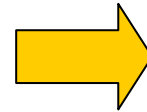
- **Reduced free volume of the polymeric system**
- **Polymer-diluent interactions, which create steric hindrance and decrease segmental mobility**
- **Stiffening action due to the presence of rigid plasticising molecules adjacent to polar groups of the polymer**
- **Increased ability of the molecules to reorient themselves, reducing the material brittleness and inhibiting the ability of cracks to propagate**

Effect of moisture adsorption on mechanical properties of toasted products

**Coffee
beans**



**various degree
of roasting**



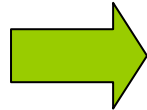
Raw (green)

Light

Medium

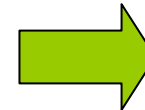
dark

**RTE breakfast
cereals**



**Different
formulation**

**Different pellet
moisture**



Corn

chestnut-

rice

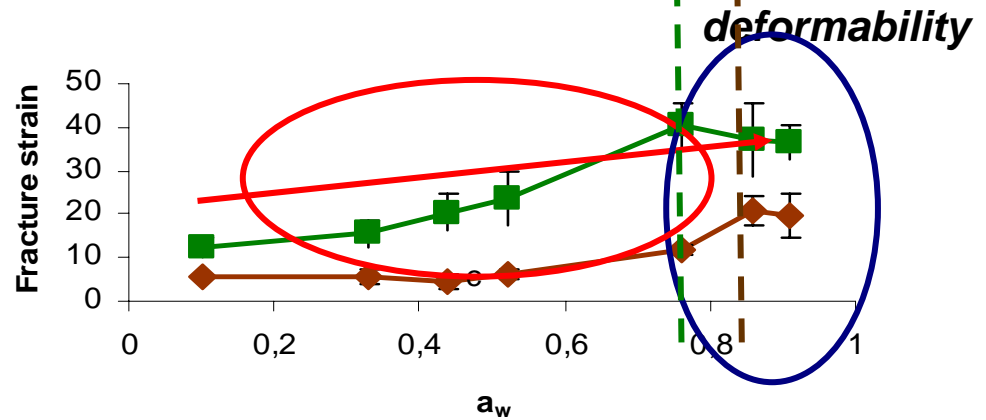
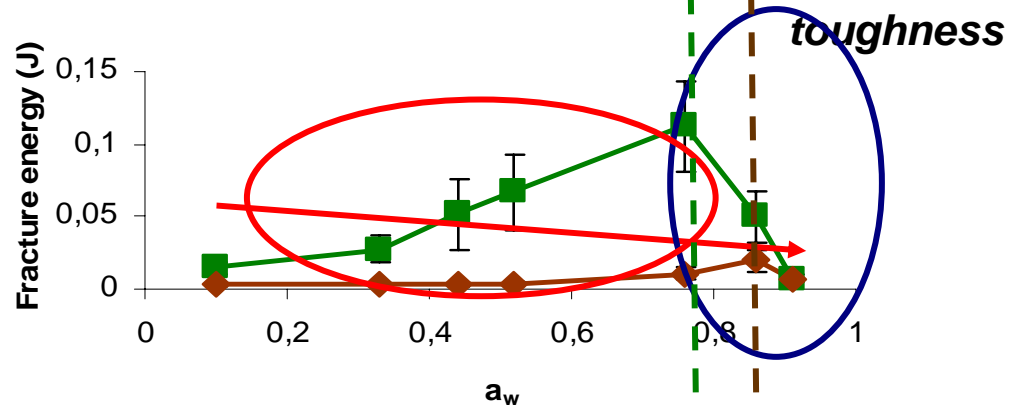
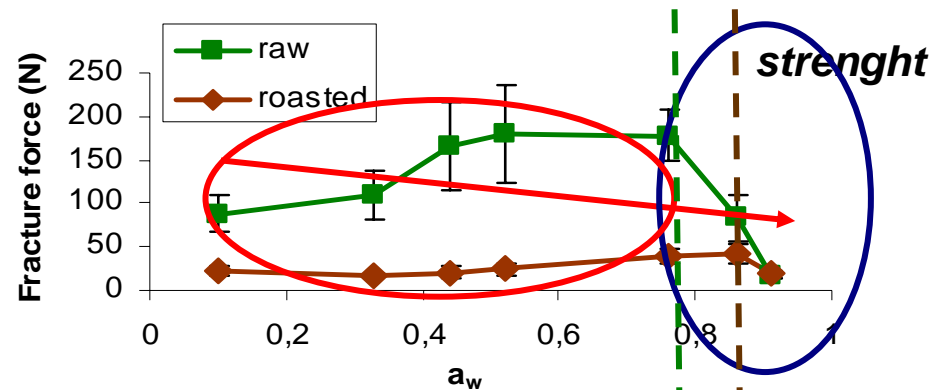
toasting

Mechanical properties of coffee beans vs water activity

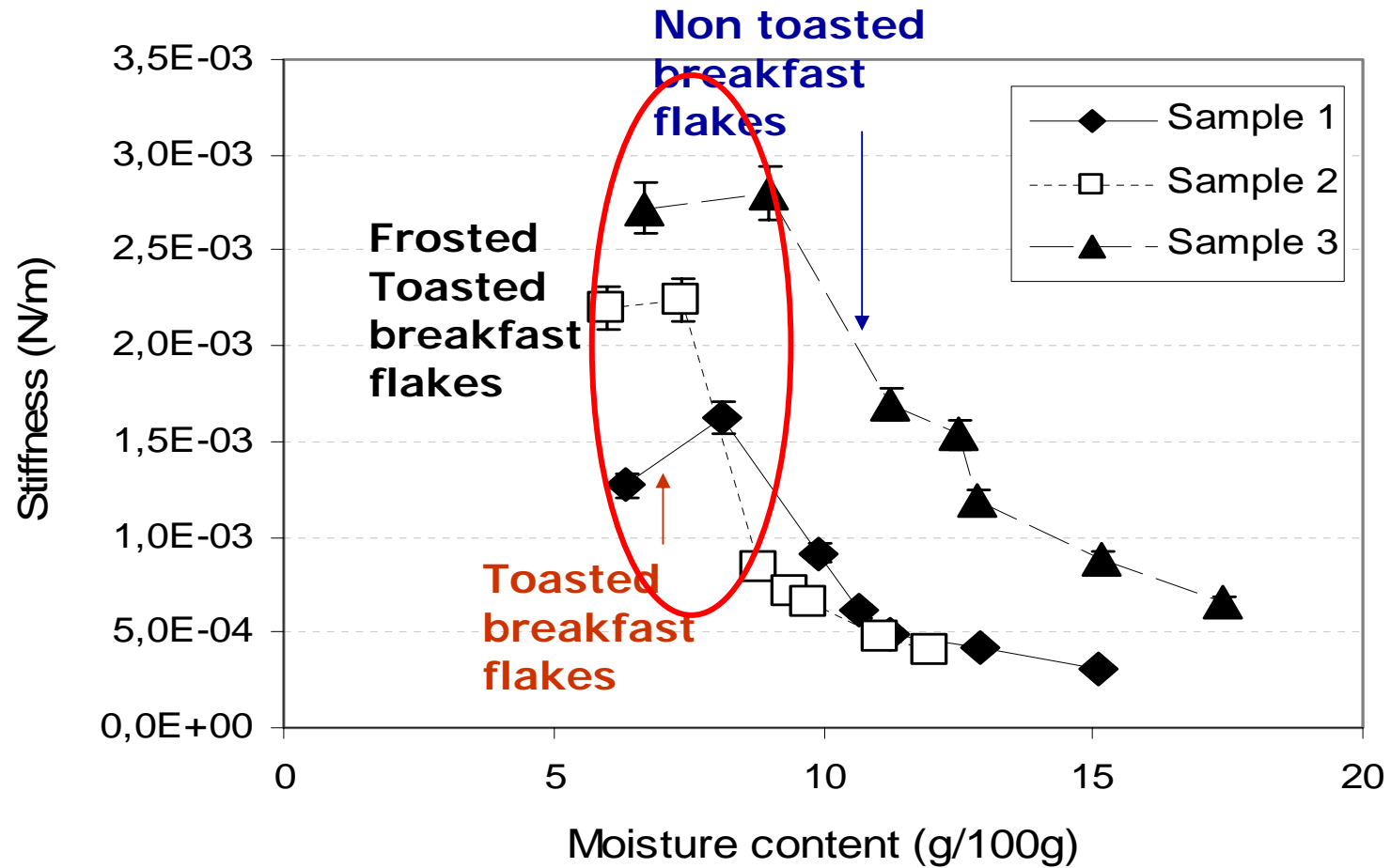
Loss of brittleness and crunchiness

PLASTICISATION EFFECT

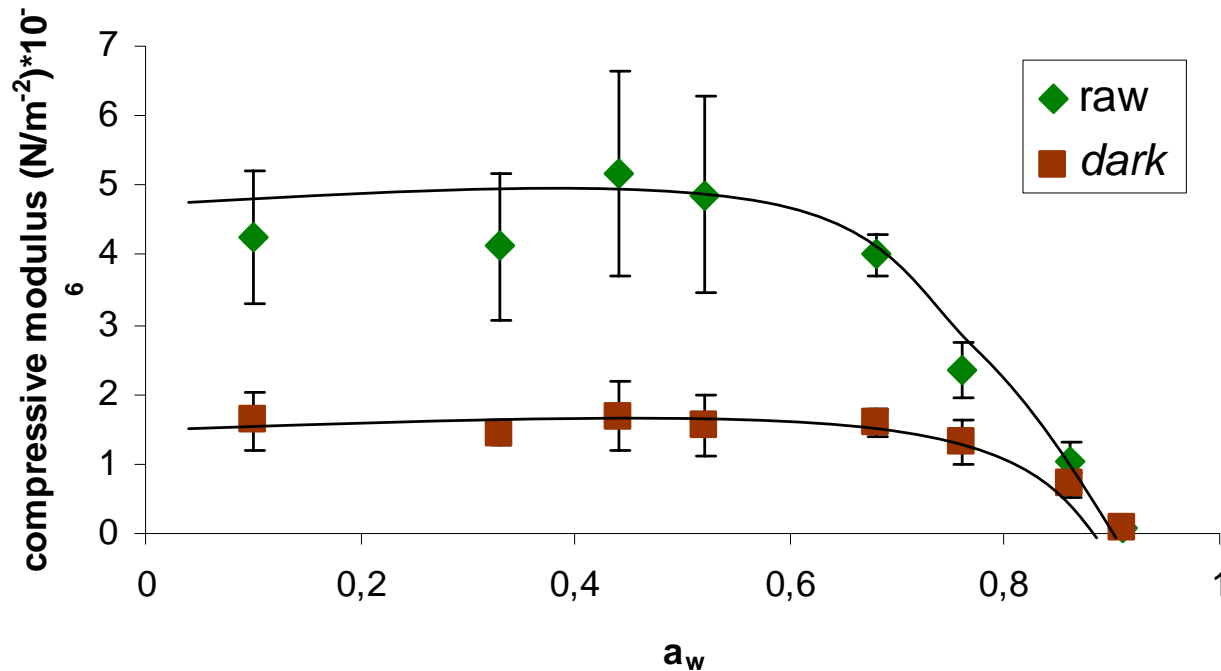
ANTIPLASTICISATION EFFECT



Effect of water on textural properties of RTE breakfast flakes



Modulus vs a_w of raw and roasted coffee beans



Fermi's equation
$$Y_{(aw)} = \frac{Y_0}{1 + e^{\frac{aw - awr}{b}}}$$

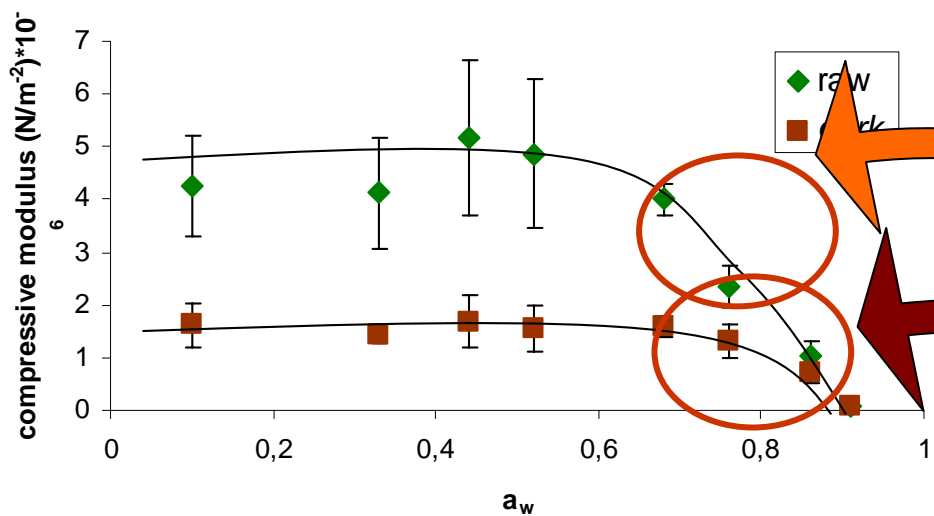
a_{wc} : a_w value at which a 50% drop of the mechanical property occurs

b: index of drop steepness

Regression parameters of Fermi's equation applied to compressive modulus upon hydration

Coffee sample	Y_0 (N m ⁻²)	a_{wC}	b	R^2
Raw	**4.61a	**0.770b	*0.053a	0.967
<i>Light</i> roasted	**2.07b	**0.834a	*0.051a	0.925
<i>Medium</i> roasted	**1.90b	**0.821a	*0.048a	0.935
<i>Dark</i> roasted	**1.57c	**0.843a	*0.036a	0.970

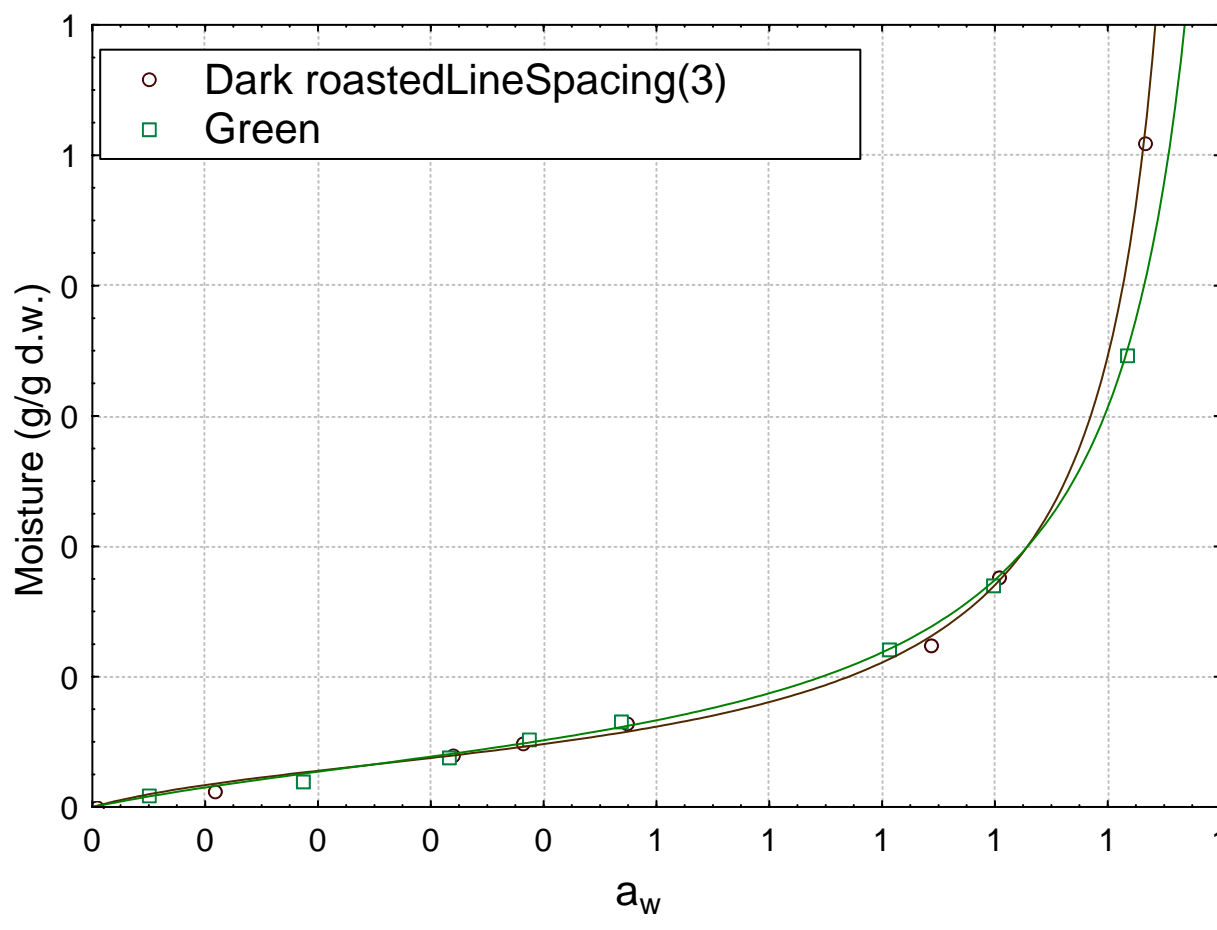
*significant at $p < 0.05$ level. **significant at $p < 0.01$ level



Coffee sample	Y_0 (N m ⁻²)	a_{wc}	b	R^2
Raw	**4.61 ^a	**0.770 ^b	*0.053 ^a	0.967
Light roasted	**2.07 ^b	**0.834 ^a	*0.051 ^a	0.925
Medium roasted	**1.90 ^b	**0.821 ^a	0.048 ^a	0.935
Dark roasted	**1.57 ^c	**0.843 ^a	*0.036 ^a	0.970

*significant at $p < 0.05$ level. **significant at $p < 0.01$ level

Water-coffee matrix interactions: sorption isotherm of raw and dark roasted coffee beans



Regression parameters of GAB equation applied to sorption isotherms

Coffee sample	X_m % d.b.	C_g	K	R^2
Raw	**4.34a	**4.29b	**0.960d	0.999
<i>Light</i> roasted	**3.58b	*3.05b	**0.991c	0.999
<i>Medium</i> roasted	**3.56b	*6.00ab	**0.998b	0.999
<i>Dark</i> roasted	**3.54b	*6.76a	**0.999a	0.999

*significant at $p < 0.05$ level. **significant at $p < 0.01$ level

Roasted samples are able to retain more water in the higher a_w range ($a_w > 0,85$)

Upward concavity: a_w 0,825

Water-coffee matrix interactions and mechanical properties

Roasted coffee beans

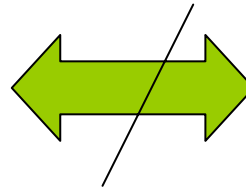
sorption isotherm:
 a_w value where water
becomes “free” (0,83)



Mechanical properties:
 a_{wc} : 0,82-0,84

Green coffee beans

sorption isotherm:
 a_w value where water
becomes “free” (0,83)



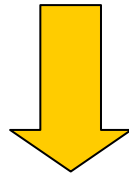
Mechanical properties
 a_{wc} : 0,77



≠ composition
≠ structure

DSC and NMR analysis (ongoing research)

Evaluation of the “state” and mobility of water in the green and roasted coffee beans matrix



Preliminary results of DSC analysis in roasted coffee:

- no freezeable water in samples $a_w \leq 0,82$
- freezeable water in samples $a_w > 0,82$

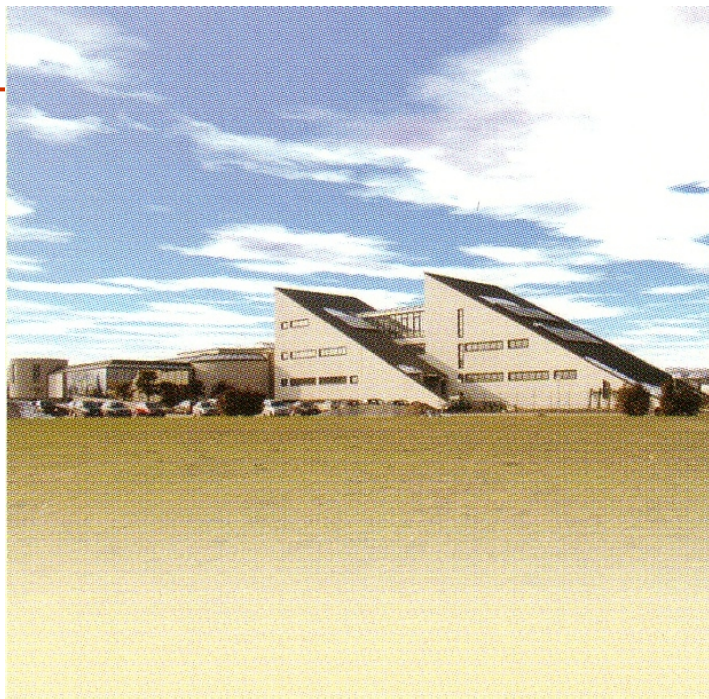
Conclusions

Antiplasticising/plasticising effect of water on toasted food matrices

Mechanical properties of coffee as affected by water reflect:

- cellular characteristics of the matrix (porosity, open-closed cells, cell wall size, distribution, thickness)
- mechanical properties of cell wall material and its moisture dependence





Dipartimento di Scienze degli Alimenti
University of Teramo
Mosciano S. Angelo