

#### Similarity in the drying behavior between biological colloids and model colloidal dispersions

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# Similarity in the drying behavior between biological colloids and model colloidal dispersions



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### LAB'S PRESENTATION





Dairy Platform



Biological Resource Centre



STLO



Structuration / destructuration mechanisms of food matrix:

from structural characterisation to digestion

> Dairy processing and cheese making:

toward sustainable dairy systems

> Microbial interaction:

food matrix and host cell



Please visit http://www6.rennes.inra.fr/stlo\_eng

## **Controlling dairy powders properties**



Strategy

background

Results

Conclusion



### Signature of milk proteins at multi-scale



.05

## Signature of milk proteins at multi-scale

Whatever the drying kinetics, same morphological behavior

- Specific signatures of WP and NPC proteins on the particle formation
- Different kinds of drying behavior
  - Whey proteins = brittle material
  - Casein micelles = ductile material

To what extent is the formation of particles affected by the protein material and its mechanical properties ?



### Material & Method : investigation of mechanical behaviors

#### **Coupling cracks dynamics and micro-indentation**



## Material & Method : milk proteins and colloidal systems

Study the drying behavior of milk proteins and model colloidal systems

#### Whey proteins

- Globular structure,  $D \approx 10-20 \text{ nm}$
- → Reconstituted from WP powder (Whey Proteins, 100 g.L<sup>-1</sup>)



#### **Dispersion of silica coloidal particles**

Ludox TM50 :  $\emptyset$  = 22 nm ± 2 (weight fraction in silica particles = 0.40)

#### **Casein micelles**

- Micellar, dynamic and hydrated structure,  $D\approx 10^2~nm$
- → Reconstituted from NPC powder (Native PhosphoCaseinates, 100 g.L<sup>-1</sup>)



Holt & Horne, 1996





Bouchoux, 2010



#### **Polymer chains on TM particles**

Ludox TM50 + PVP (40kDa)

(weight concentration of PVP = 0.1%)





### **Results – Drying process of sessile drops (WP / TM50)**



#### Experimental conditions:

- Temperature: 20°C
- Relative humidity: 40%
- Initial contact angle : 31 ± 2°
  - 2 R<sub>0</sub> = 8 mm

 $\succ$ 

Evaporation rate : 8.10<sup>-8</sup> m.s<sup>-1</sup>

### **Comparable behavior** Formation of radial fractures in the solid periphery



| Scientific<br>background | Strategy | Results | Conclusion | .09 |
|--------------------------|----------|---------|------------|-----|
| background               |          |         |            |     |

### **Results – Crack dynamics and delay time before cracking**



Scientific background

Strategy

Results

Conclusion

.010

### **Results – Drying process of sessile drops** (NPC / TM50 + PVP)



#### Experimental conditions:

- Temperature: 20°C
- Relative humidity: 40%
- Initial contact angle : 35 ± 2°
  - 2 R<sub>0</sub> = 8 mm

 $\triangleright$ 

Evaporation rate : 8.10<sup>-8</sup> m.s<sup>-1</sup>

### **Comparable behavior** Later nucleation of a few, random fractures



|  | Scientific<br>background | Strategy | Results | Conclusion | .011 |
|--|--------------------------|----------|---------|------------|------|
|--|--------------------------|----------|---------|------------|------|

### Results – Crack dynamics and delay time before cracking



Strategy

Results

Conclusion

Scientific

background

.012



### **Results – Mechanical behavior & viscoelastic relaxation time**



|            | Viscosity<br>$\eta$ (GPa.s) | Elastic modulus $E_2$ (GPa) | Viscoelastic<br>relaxation<br>time, <i>tη</i> (s) |
|------------|-----------------------------|-----------------------------|---|
| WP         | 99 ± 5                      | $3.50 \pm 1.10^{-3}$        | 28 ± 2  |
| TM50       | 82 ± 5                      | $3.20 \pm 1.10^{-3}$        | 26 ± 2  |
| NPC        | 119 ± 5                     | 0.96 ± 1.10 <sup>-3</sup>   | 124 ± 5   |
| TM50 + PVP | 115 ± 5                     | $0.98 \pm 1.10^{-3}$        | 129 ± 5   |

- Penetration depth deeper for NPC and TM50 + PVP than for WP layer and TM50
- Values of viscoelastic relaxation time are similar between WP / TM50 and NPC / TM50 + PVP



Strategy Results

Scientific

background



### **Results – Drying stress and poro-elasticity**

• Drying stress at the film/air interface :

$$\sigma(z=h)\sim E\frac{t}{t_D} ~~{\rm where}~{\rm t_D}~{\rm is~the~evaporation~timescale~(h/V_{\rm E})}$$

• Max stress leading to crack when:

$$\sigma(z=h) \approx -P_{cap} \approx 5 \frac{\gamma_{air/water}}{r_{pore}}$$

Hypothesis: delay time before stress reaches max stress : viscoelastic timescale  $\,t_{\eta}$ 

$$E\frac{t_{\eta}}{t_D} \sim 5\frac{\gamma_{air/water}}{r_{pore}} \Rightarrow r_{pore}$$

estimation of the pore size in the solid state :

$$r_{pore (WP)} / r_{pore (NPC)} \sim 2$$

Results in concordance with drying behavior (NPC more deformable than WP)

|                  | AGRO<br>CAMPUS |
|------------------|----------------|
| SCIENCE & IMPACT | OUEST          |

Scientific background Strategy

Results Conclusion





## Merci

drop of a silica dispersion

drops of a silica disperison + PVP solutions of increasing concentration

\_\_\_\_Thank you for your attention



SCIENCE & IMPAC



### **More information**

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