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Characterization of the droplet-particle transition in dairy colloidal mixes

The impact of the molecular scale on particle morphology

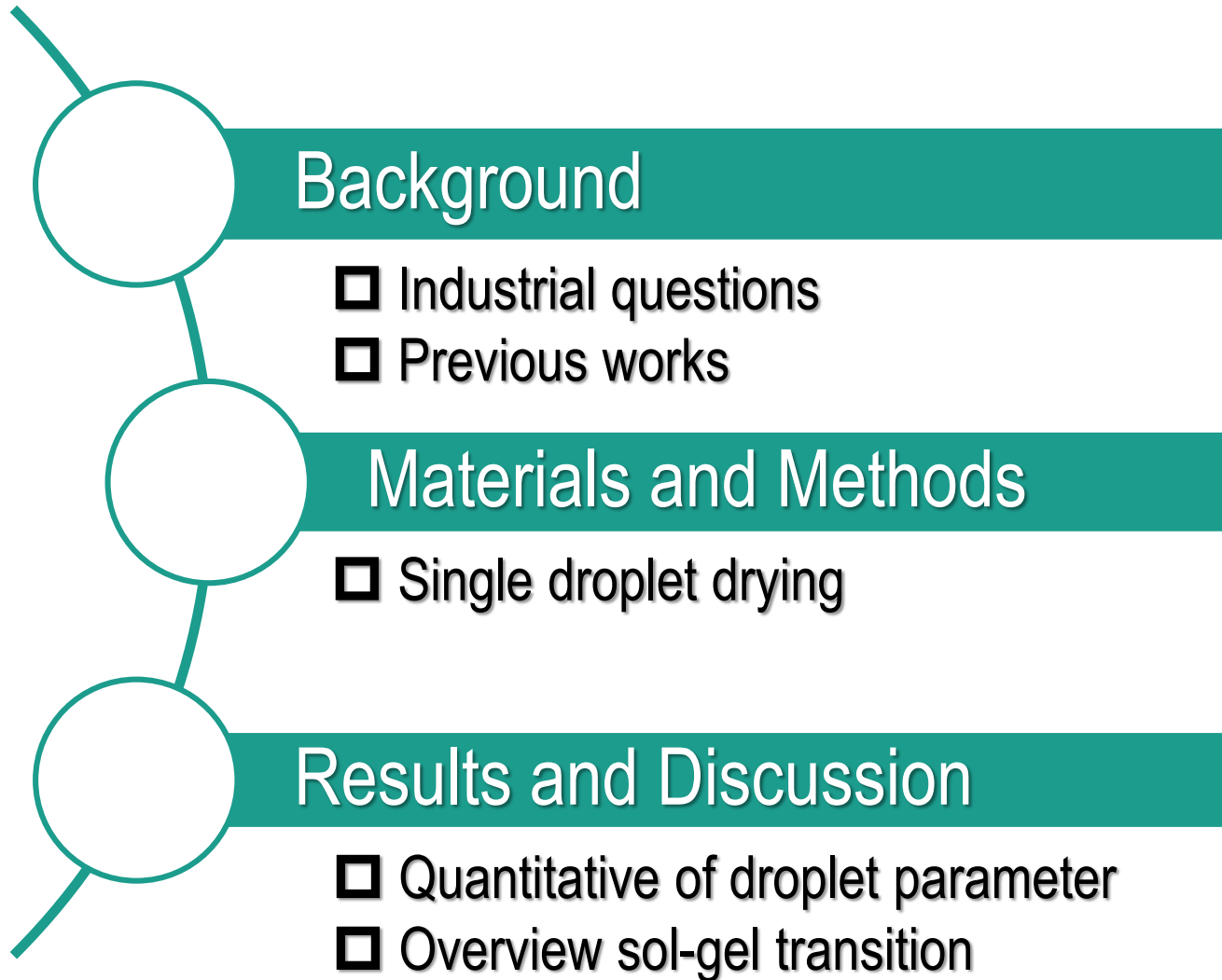


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19.11.2019



Context



Infant milk formula: the gold rush!



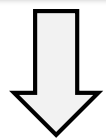
IMF market : the key dairy industry challenge

- Globalization, economical transition and population growth
- From 2007, 8-20% annual growth → 2 million tons produced /year
- **High added value** ▷ 80% of the European dairy investment since 2011

Mimicking breast milk

g/l	Cow milk	Human milk
Proteins	32	10
Caseins	80%	35%
Whey proteins	20%	65%

Adapted to their nutritional target

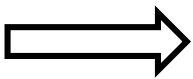


Controlled functional end-use properties

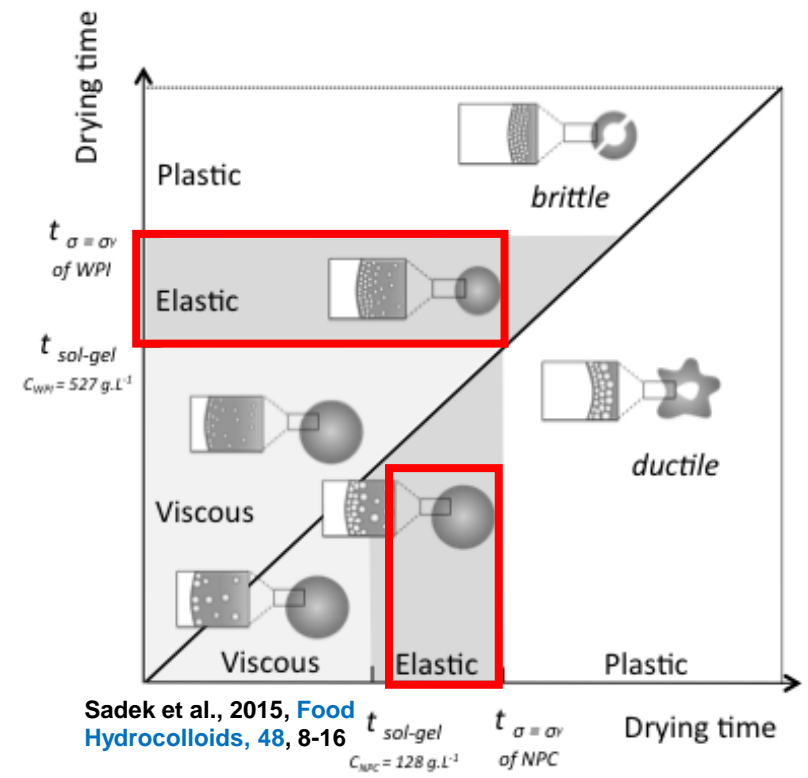
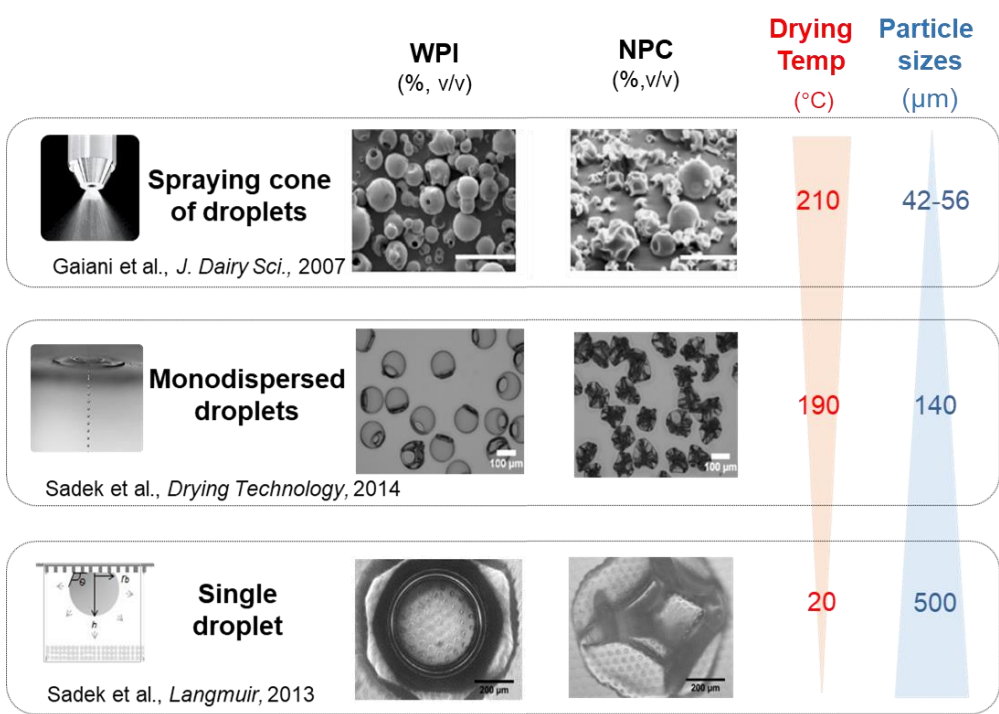
Whey protein isolates (WPI)

Native phosphocaseinates (NPC)

Simplify the milk system



Drying of dairy proteins by multiscale approach

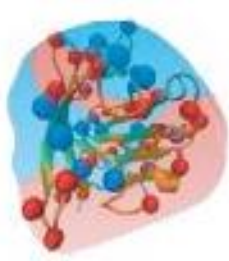


T, D
Drying scales \rightarrow Particle shape

- ✓ Protein type affects the particle shape
- ✓ The skin formation in sol-gel transition stage leads to specific particle shape

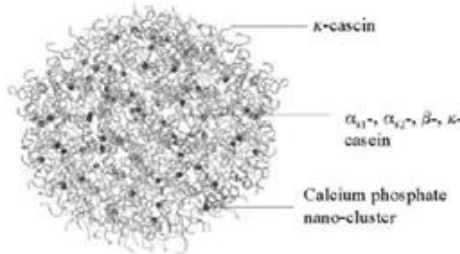
How the composition of WPI/NPC affects the **sol-gel transition**

Materials



Whey protein isolates (WPI)

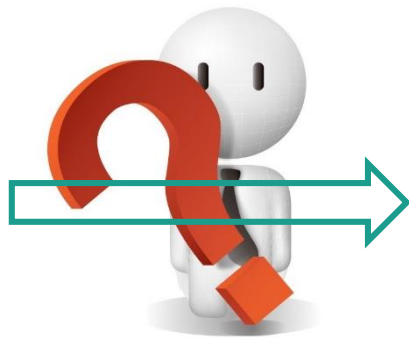
- Globular rigid structure
- $D \approx 10 \text{ nm}$



Native phosphocaseinates (NPC)

- Micellar, dynamic and hydrated structure
- $D \approx 10^2 \text{ nm}$

WPI/NPC ratio



Particle forming process (Sol gel transition)

WPI relative percentage:
0, 20, 50, 80 and 100%

Concentration

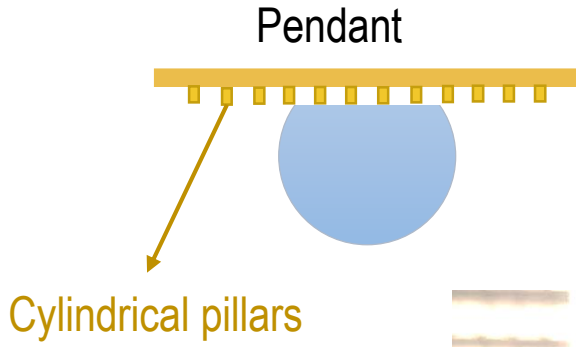
8 wt. %

Drying conditions

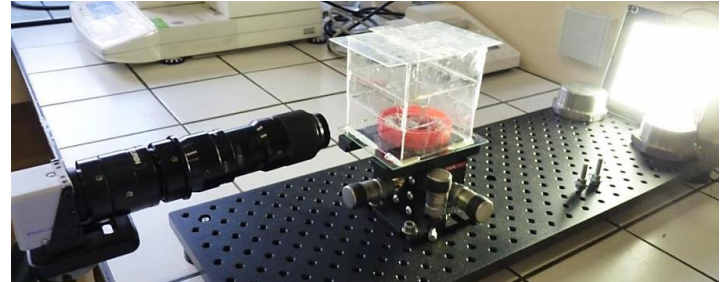
- Temperature: 20 °C
- Initial size: 0.5 μ L
- Relative Humidity: < 2 %

Single droplet drying

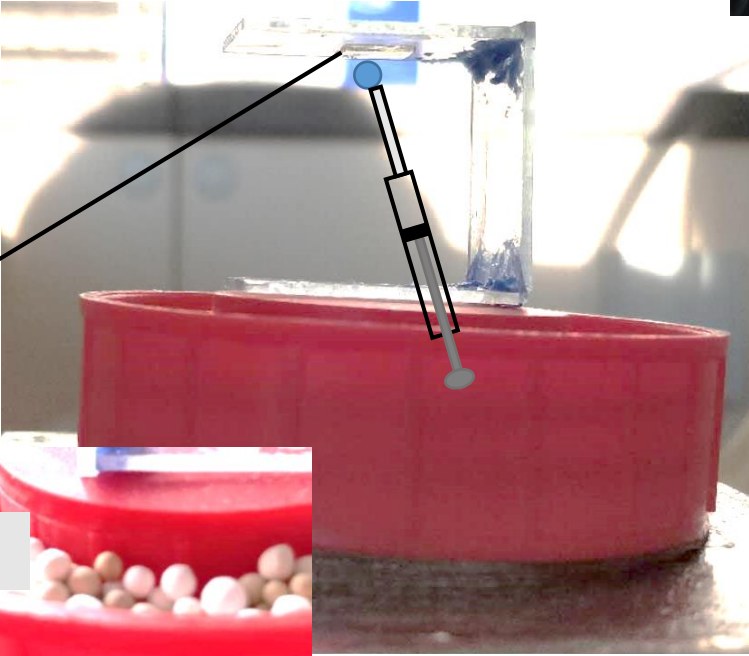
4. Bias light



3. High-speed camera



2. PDMS (poly dimethyl siloxane) support



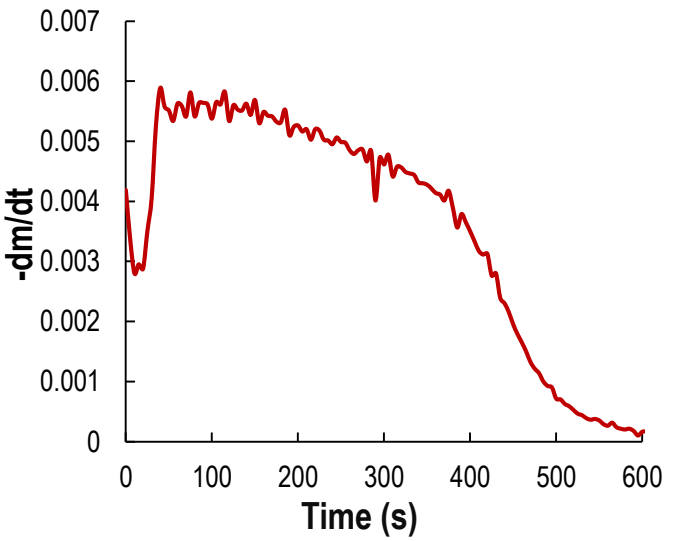
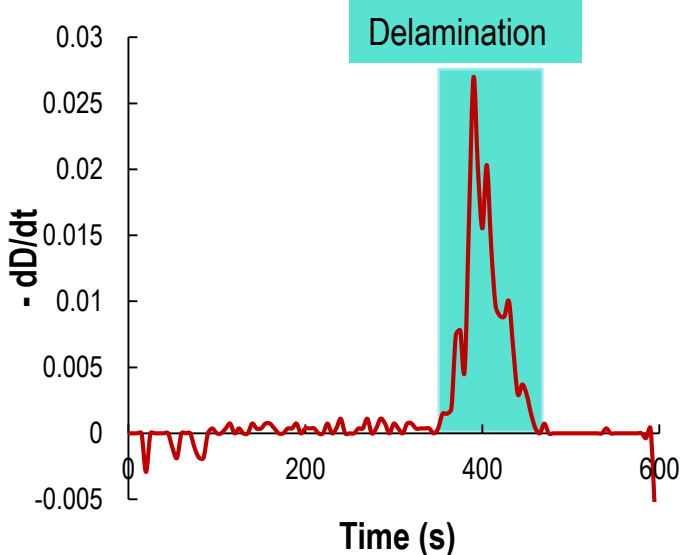
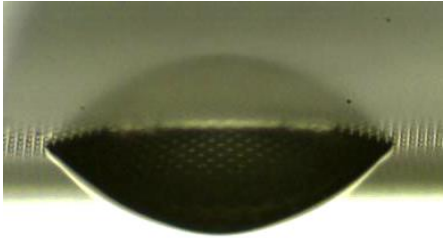
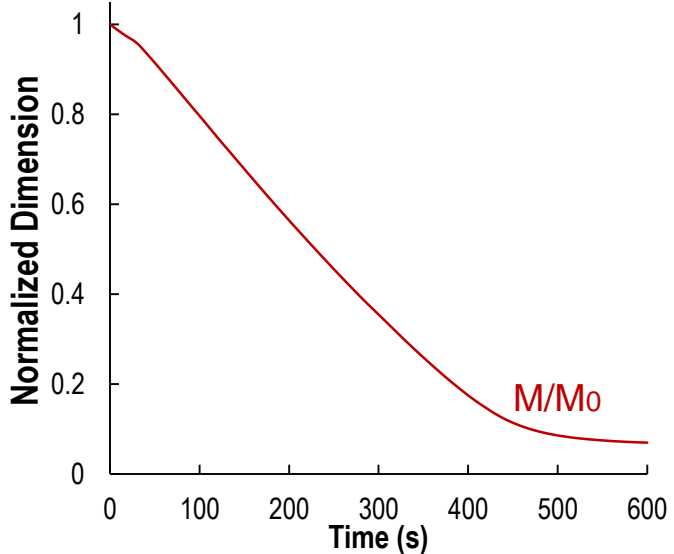
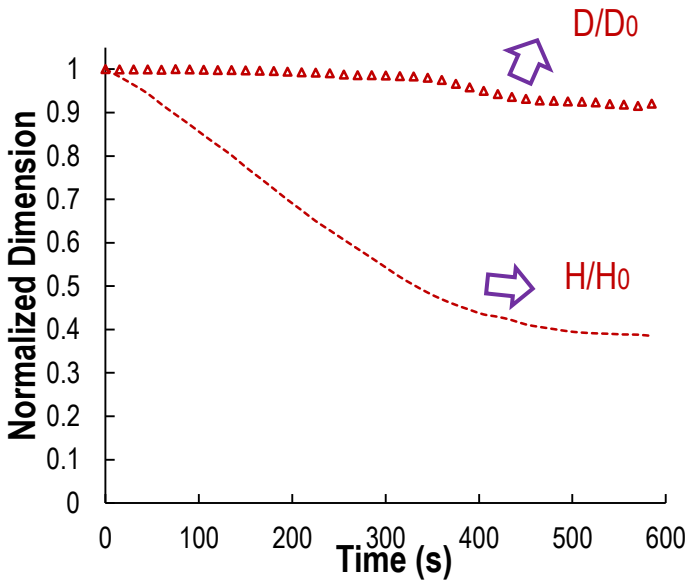
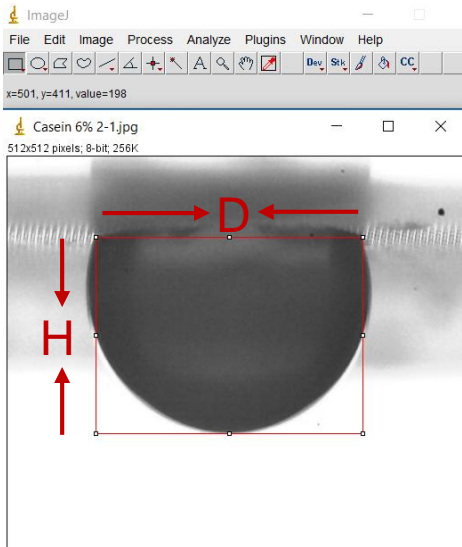
1. Zeolites



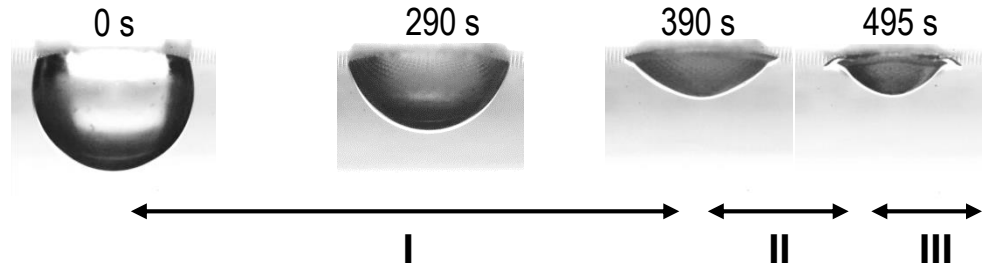
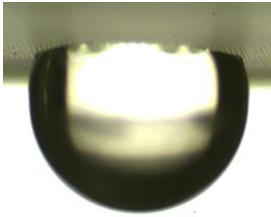
**Micro-balance
Drying kinetics**



Image and data analysis



Morphological evolution of WPI

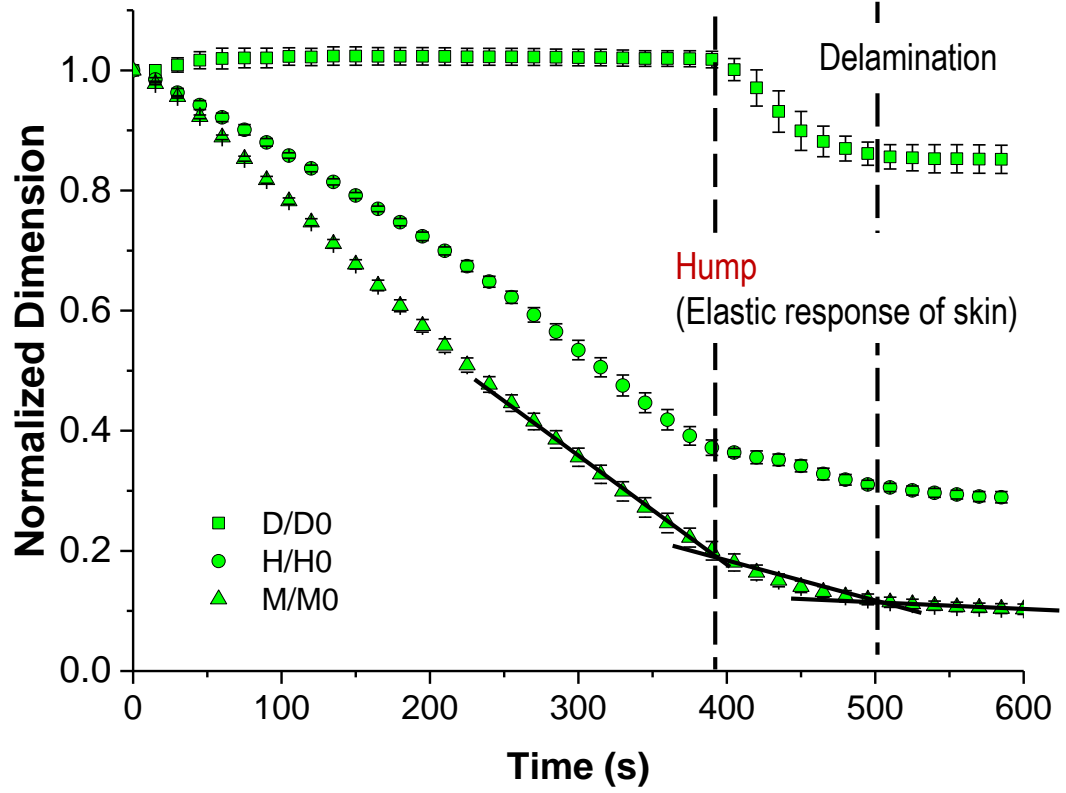


Stage I: droplet shrinkage with constant rate.

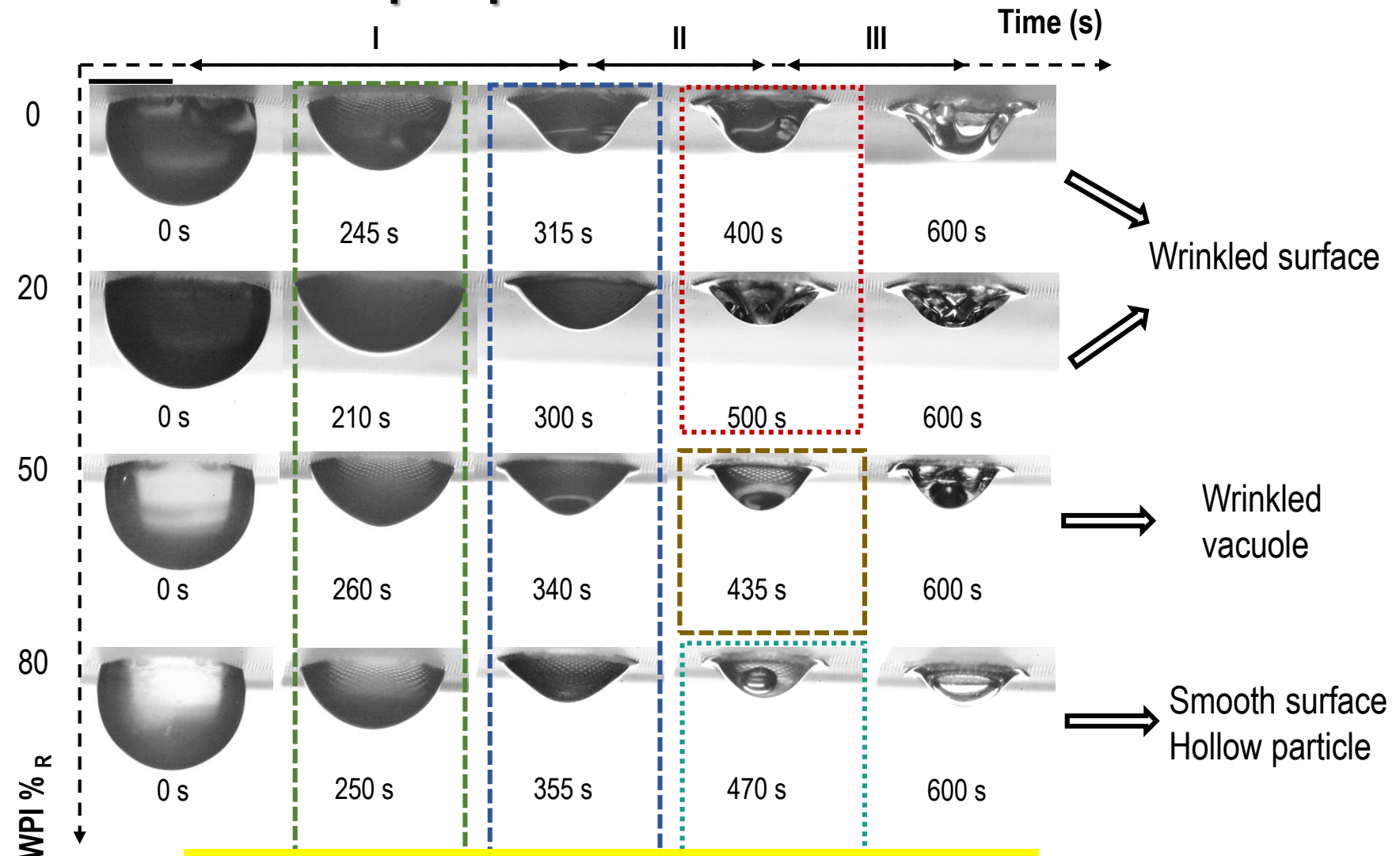
Stage II: border delamination + elastic response of skin.

Stage III: the shape is constant.

Drying kinetics correspond to the profile view curves.

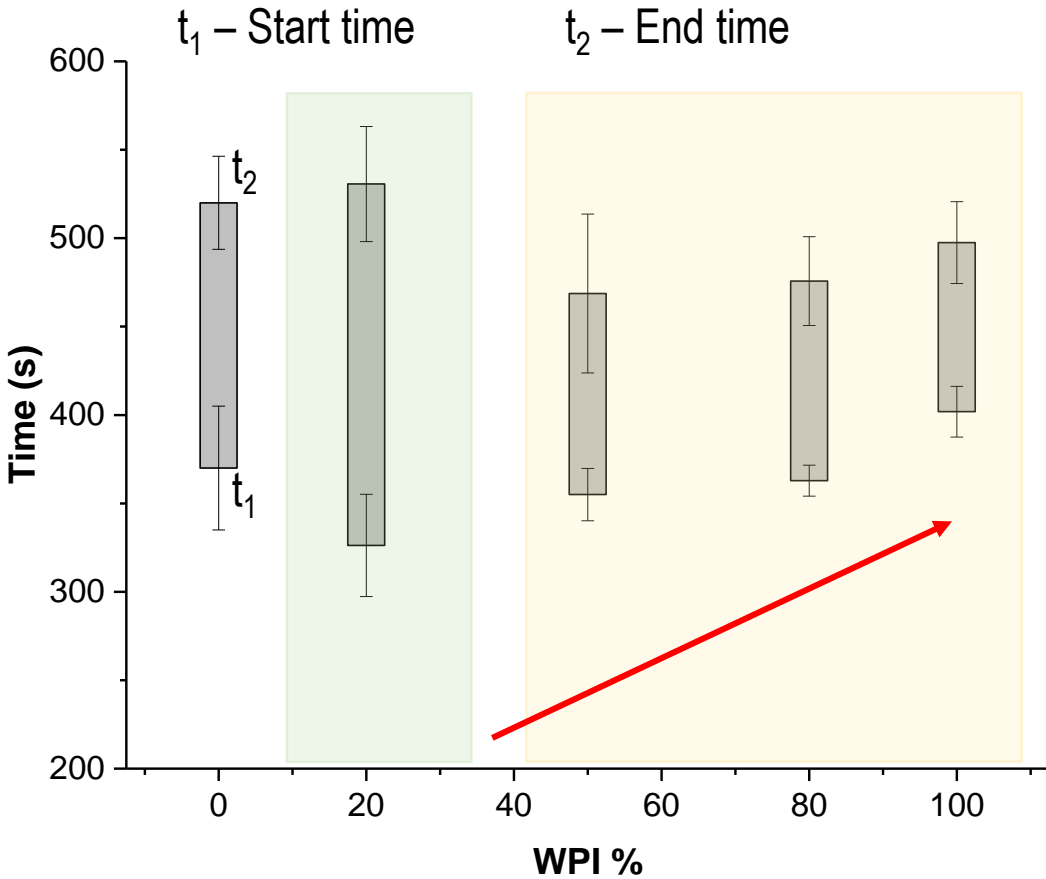


Visualization of droplet profile



Stage II is crucial to understand the particle formation

Overview of the Stage II (Sol-gel transition)

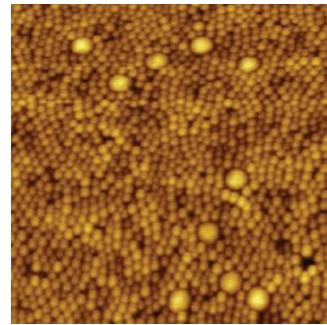


➤ Stage II earlier in mixes

NPC retain water

➤ WPI ≥ 50%: Stage II almost constant

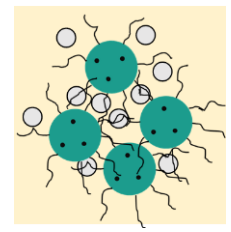
THE SKIN IS MORE RIGID (SMALL-ON-TOP)



Trueman R E, 2012, *Langmuir*, 28(7), 3420-3428.
 Trueman R E, 2012, *Journal of Colloid & Interface Science*, 2012, 377(1):207-212.
 Lanotte et al., 2018, *Colloids and Surfaces*, 20, 0927-7757
 Fortini A, *Journal Physical Review Letters*, 2017

➤ WPI = 20% Stage II is the earliest and longest

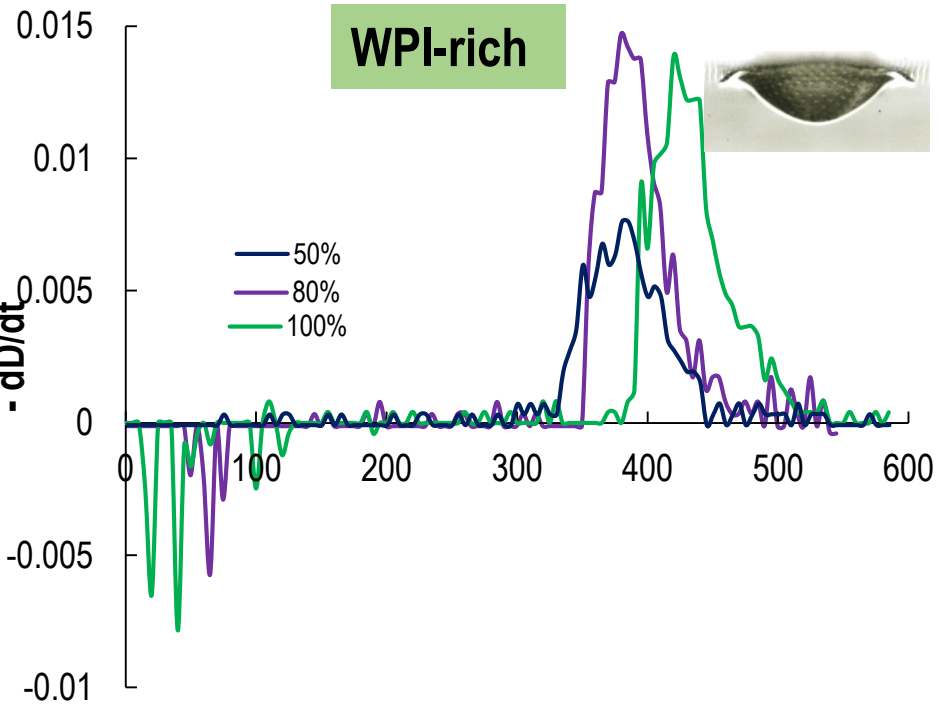
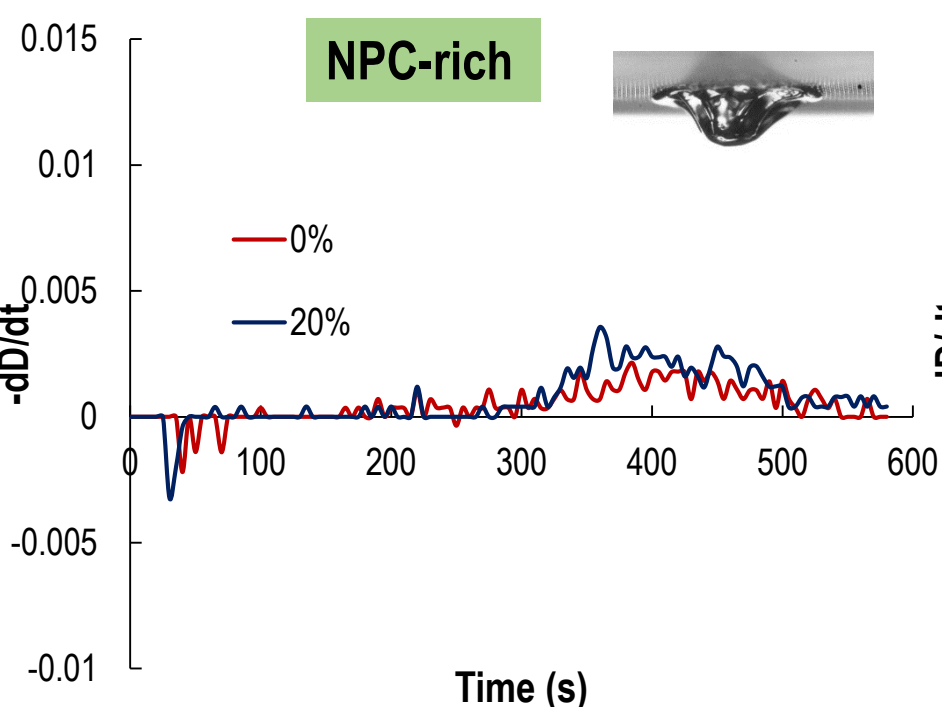
STAGE II = DELAMINATION + SKIN ELASTIC RESPONSE



WPI enters into the NPC structure.



The delamination of WPI/NPC mixture samples



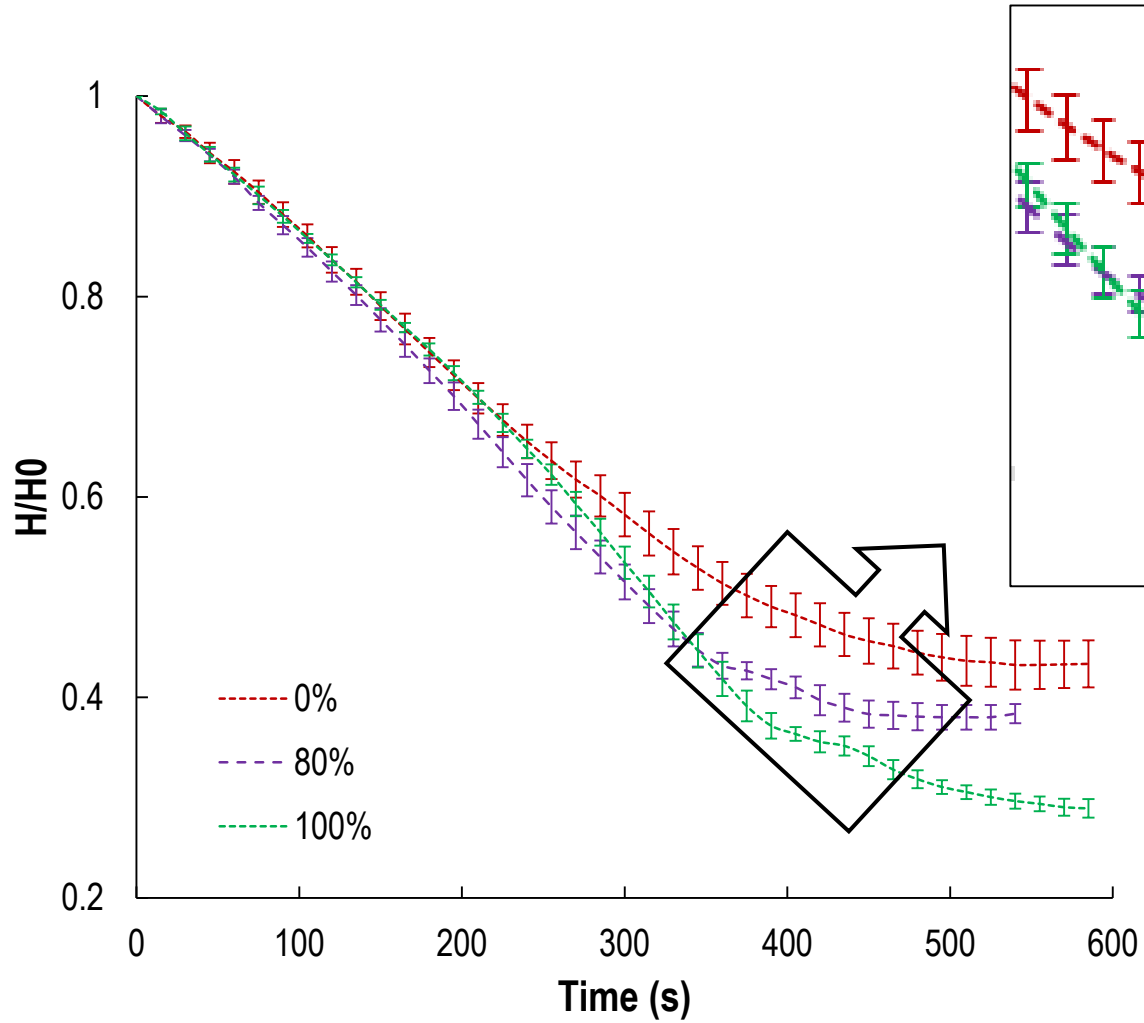
NPC: no delamination
WPI: stronger delamination
Mixing?



Few NPC promote delamination
Massive NPC weaker delamination

➤ Delamination affect by WPI%

The effect of $WPI\%_{0R}$ on elastic response of skin



- Skin deformation in mixes is earlier than in pure WPI
- Sol-gel transition stage affected by composition of sample

Summary

- **Quantification** of the morphology parameters of droplet during the drying process we get more information.
- Impact of WPI/NPC ratio on the sol-gel transition stage:

Delamination and skin mechanical response.

- The sol-gel transition stage is **delayed** with increasing WPI %_R.
- The evaporation rate is hindered in sol-gel transition stage.

Skin layer structure.

Merci



谢谢

***Thanks for your
attention***

More information:

- Sadek et al., 2013, [Langmuir](#), **29**, 15606-15613
- Sadek et al., 2014. [Drying Technol](#),**32**, 1540-1551
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- Sadek et al., 2015, [Food Hydrocolloids](#), **48**, 8-16
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- Bouchoux A et al.,2010, [Biophysical Journal](#), **99**, 3754-3762.
- Trueman R E, 2012, [Langmuir](#), **28**(7), 3420-3428.
- Trueman R E, 2012, [Journal of Colloid & Interface Science](#), **377**(1):207-212.
- YF Yano et al.,2012, [Journal of Physics: Condensed Matter](#)
- Lanotte et al., 2018, [Colloids and Surfaces](#),**20**, 0927-7757
- Fortini A, [Journal Physical Review Letters](#), 2017