Characterization of the droplet particle transition in dairy colloidal mixes: The impact of the molecular scale on particle morphology

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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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Context

Background

- Industrial questions
- Previous works

Materials and Methods

- Single droplet drying

Results and Discussion

- Quantitative of droplet parameter
- Overview sol-gel transition

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

⇩

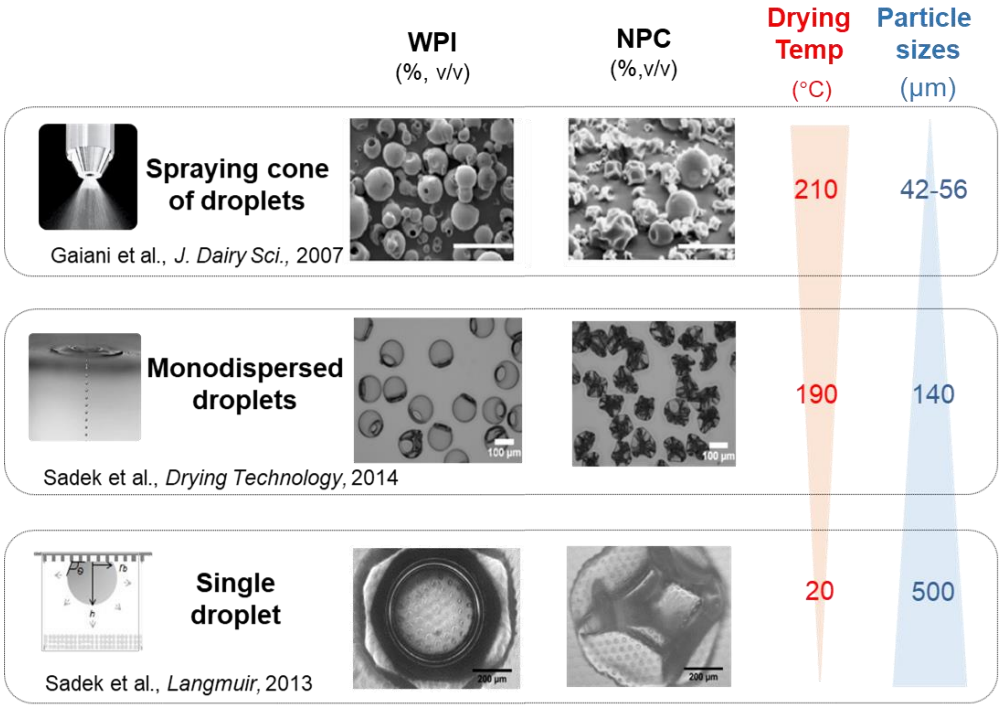
Controlled functional end-use properties

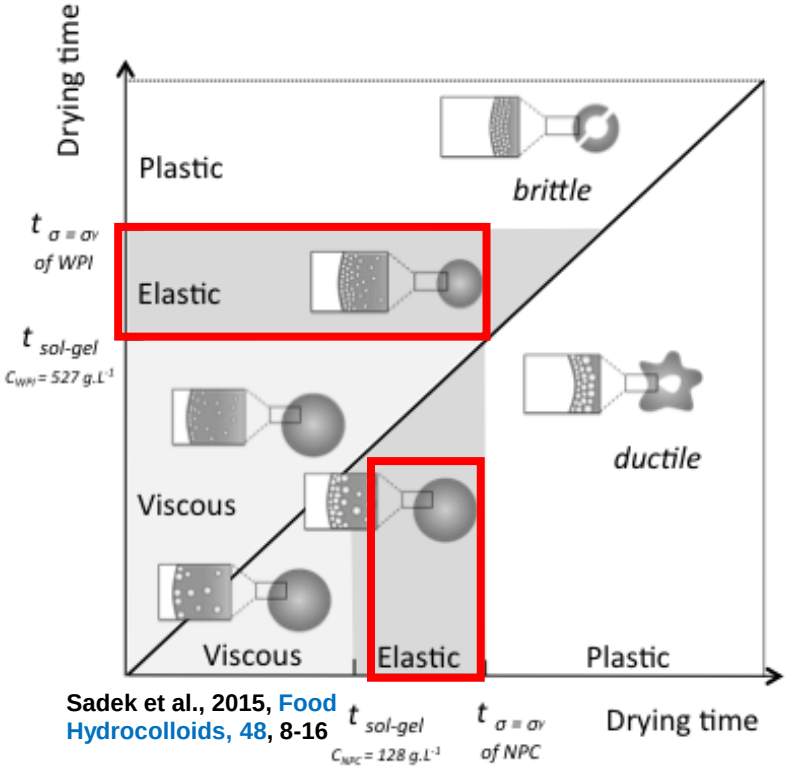
Simplify the milk system ⇨

Whey protein isolates (WPI)

Native phosphocaseinates (NPC)

Drying of dairy proteins by multiscale approach





Sadek et al., 2015, Food Hydrocolloids, 48, 8-16

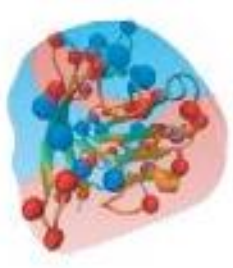
T, D
Drying scales

≠ Particle shape

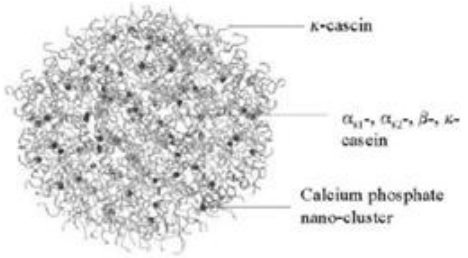
- ✓ Protein type affects the particle shape
- ✓ The skin formation in sol-gel transition stage leads to specific particle shape

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

Materials



Whey protein isolates
(WPI)

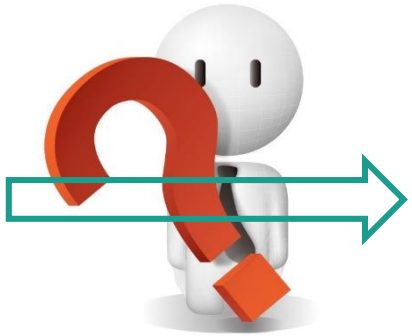


Native phosphocaseinates
(NPC)

- Globular rigid structure
- D ≈ 10 nm

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

WPI/NPC ratio



Particle forming process
(Sol gel transition)

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

Concentration

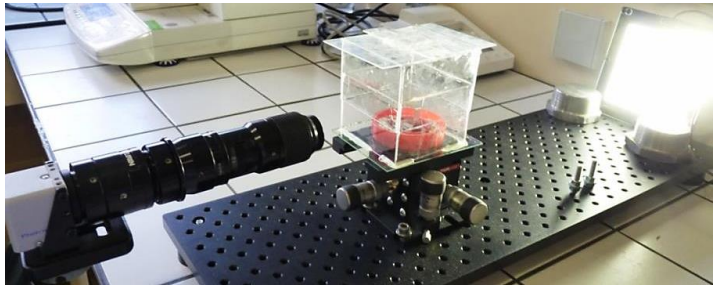
8 wt.%

Drying conditions

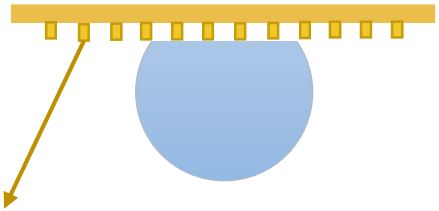
- Temperature: 20 °C
- Initial size: 0.5 µ L
- Relative Humidity: < 2 %

Single droplet drying

4. Bias light

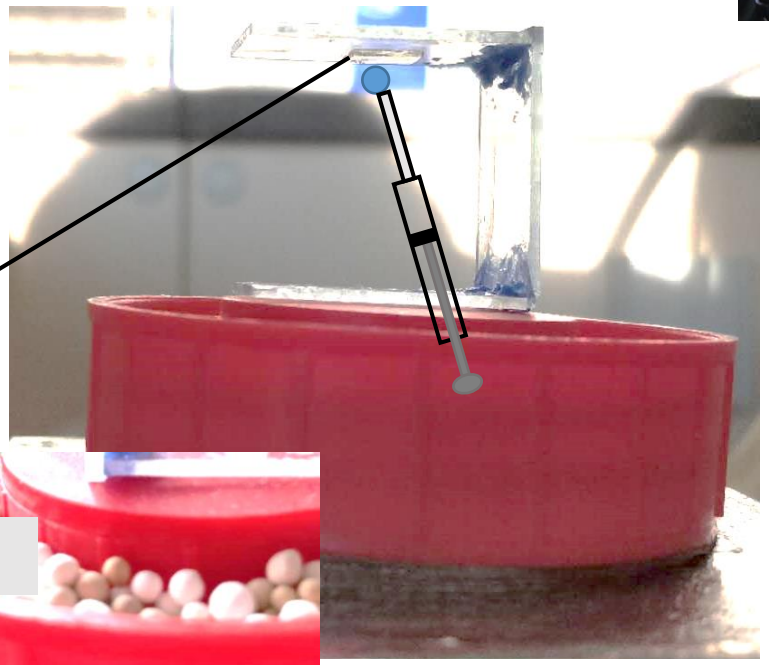


Pendant



3. High-speed camera

Cylindrical pillars

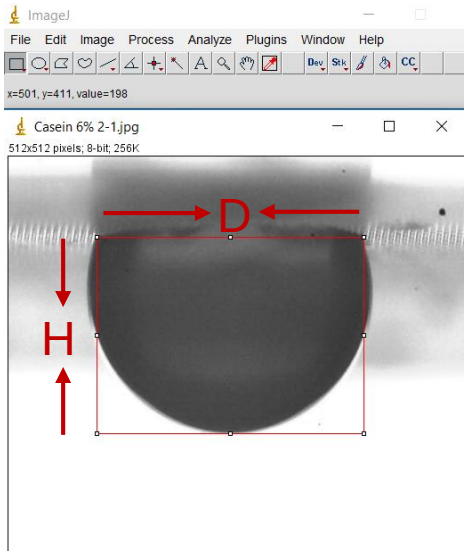


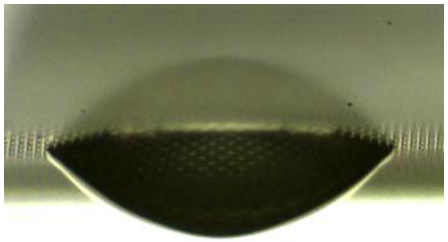
2. PDMS (poly dimethyl siloxane) support

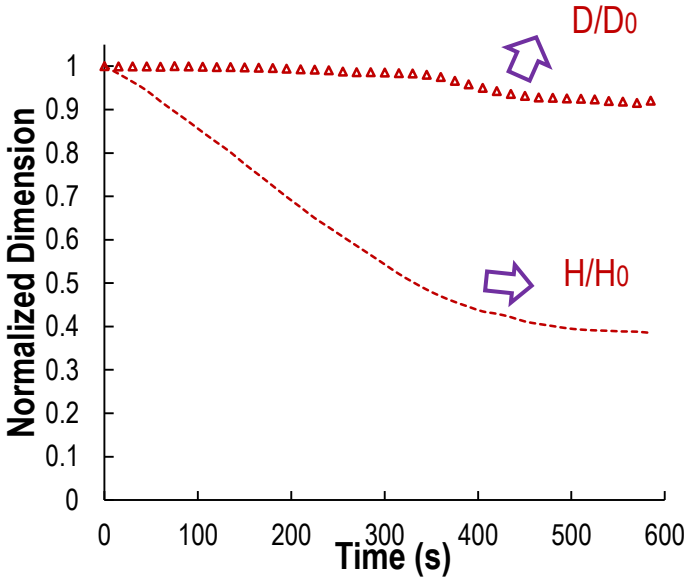
1. Zeolites

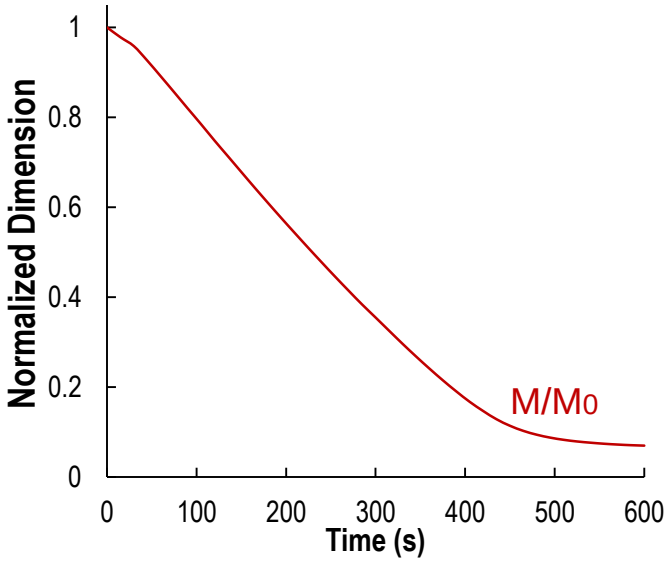
Micro-balance
Drying kinetics

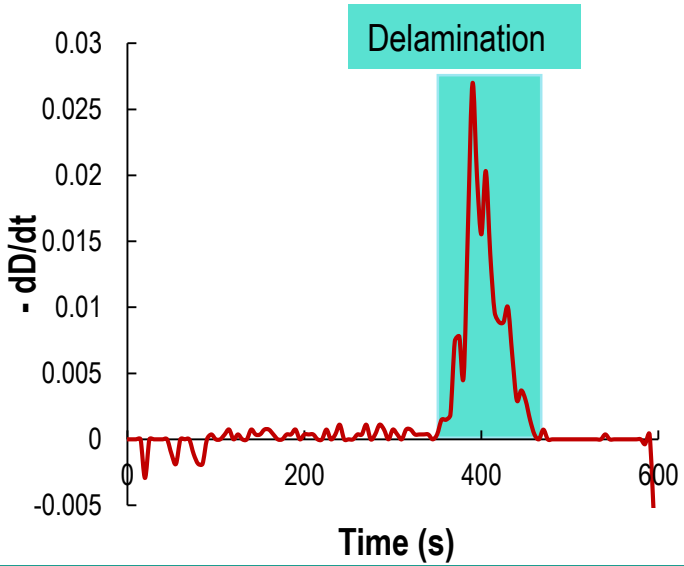
Image and data analysis

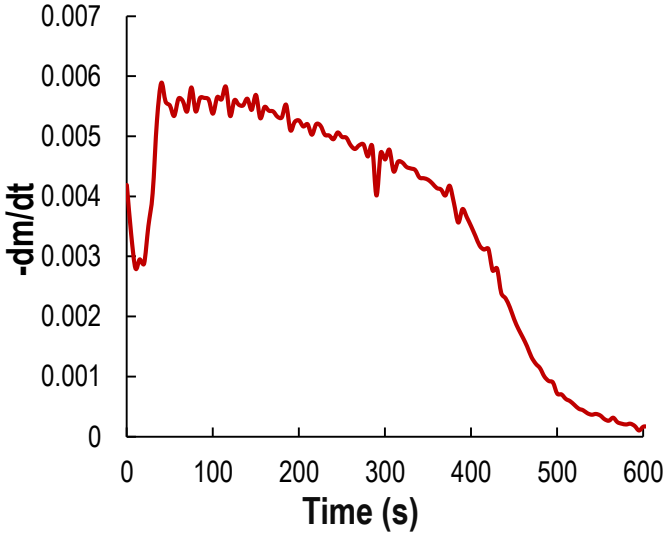




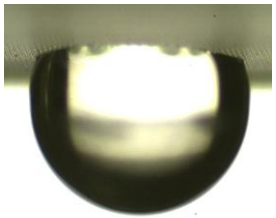


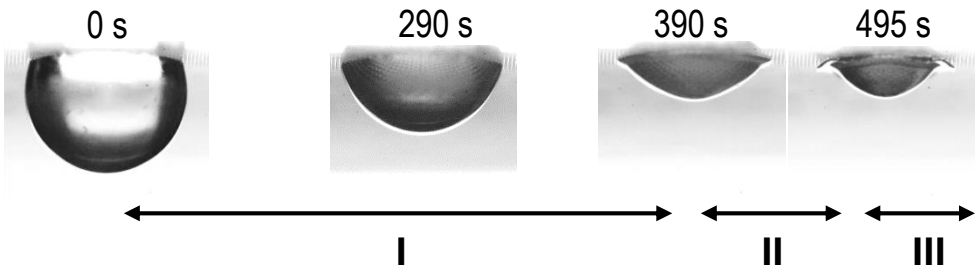






Morphological evolution of WPI



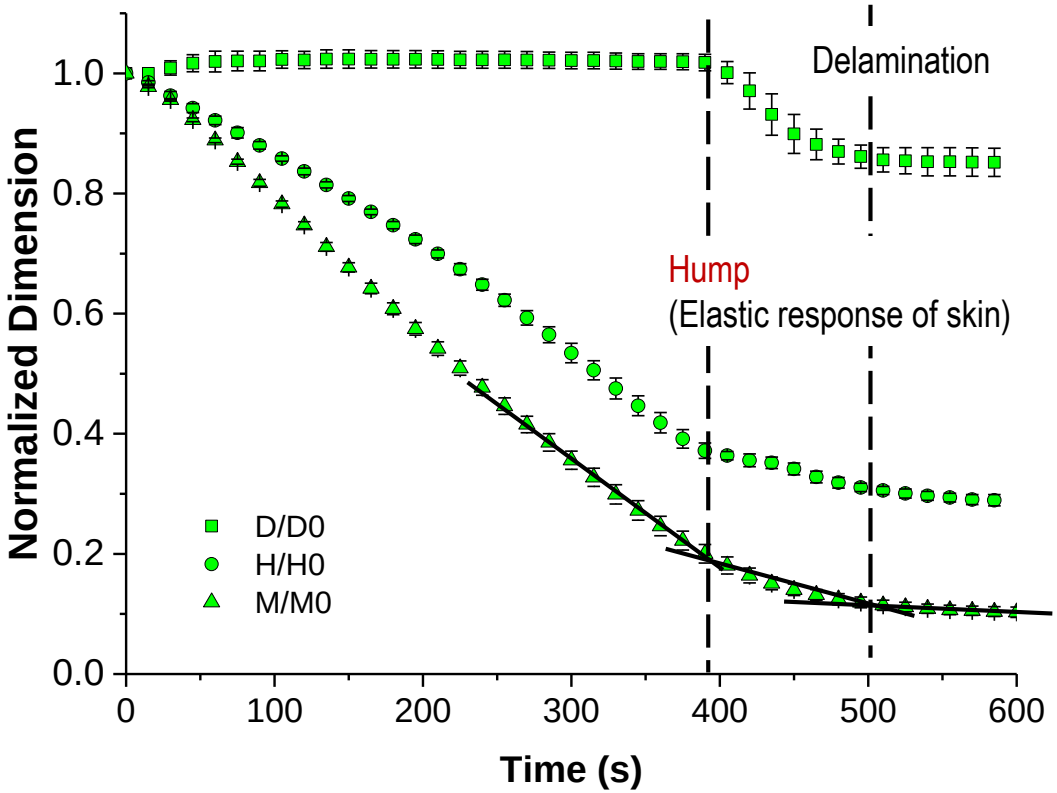


Stage I: droplet shrinkage with constant rate.

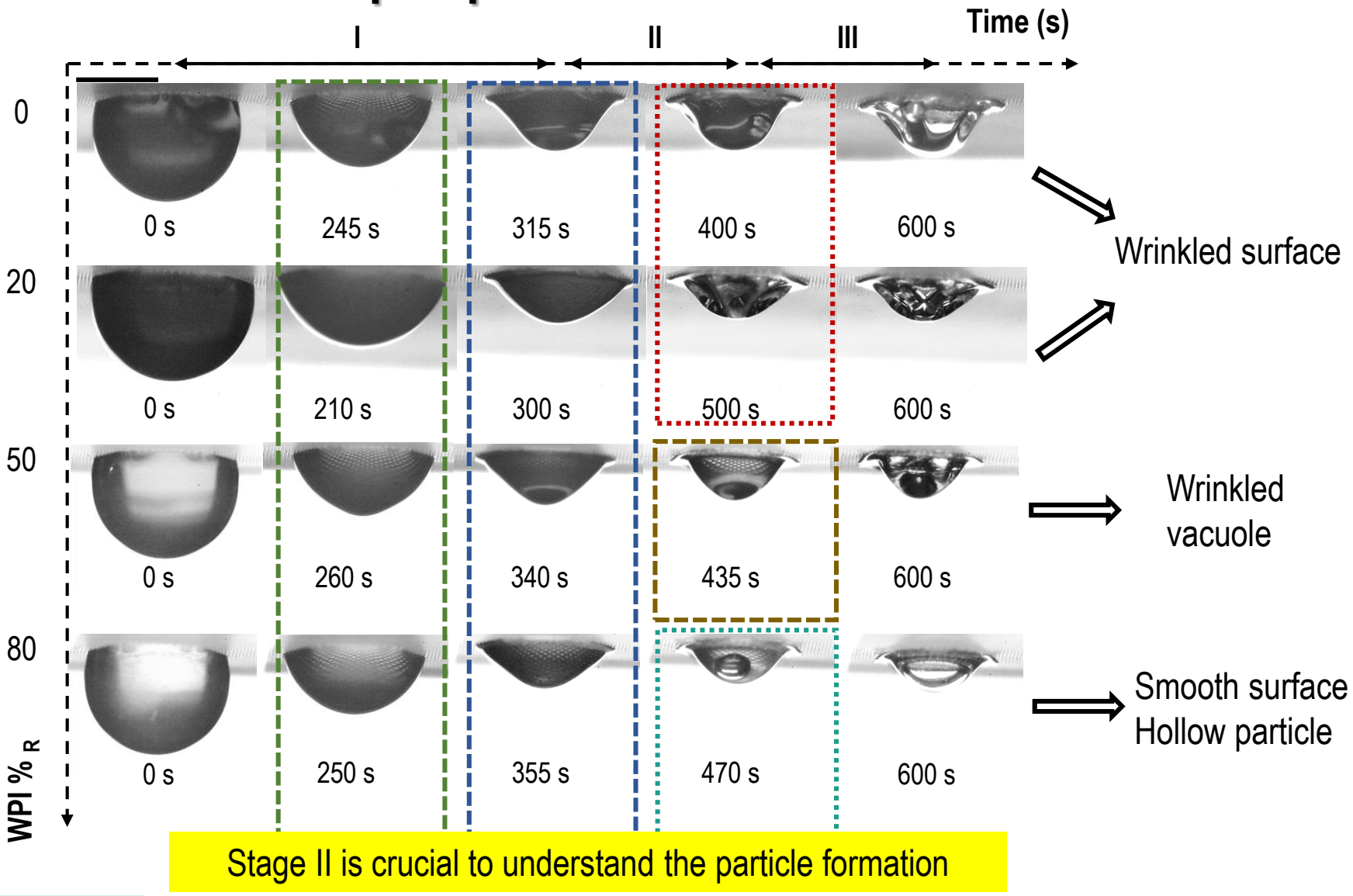
Stage II: border delamination + elastic response of skin.

Stage III: the shape is constant.

Drying kinetics correspond to the profile view curves.

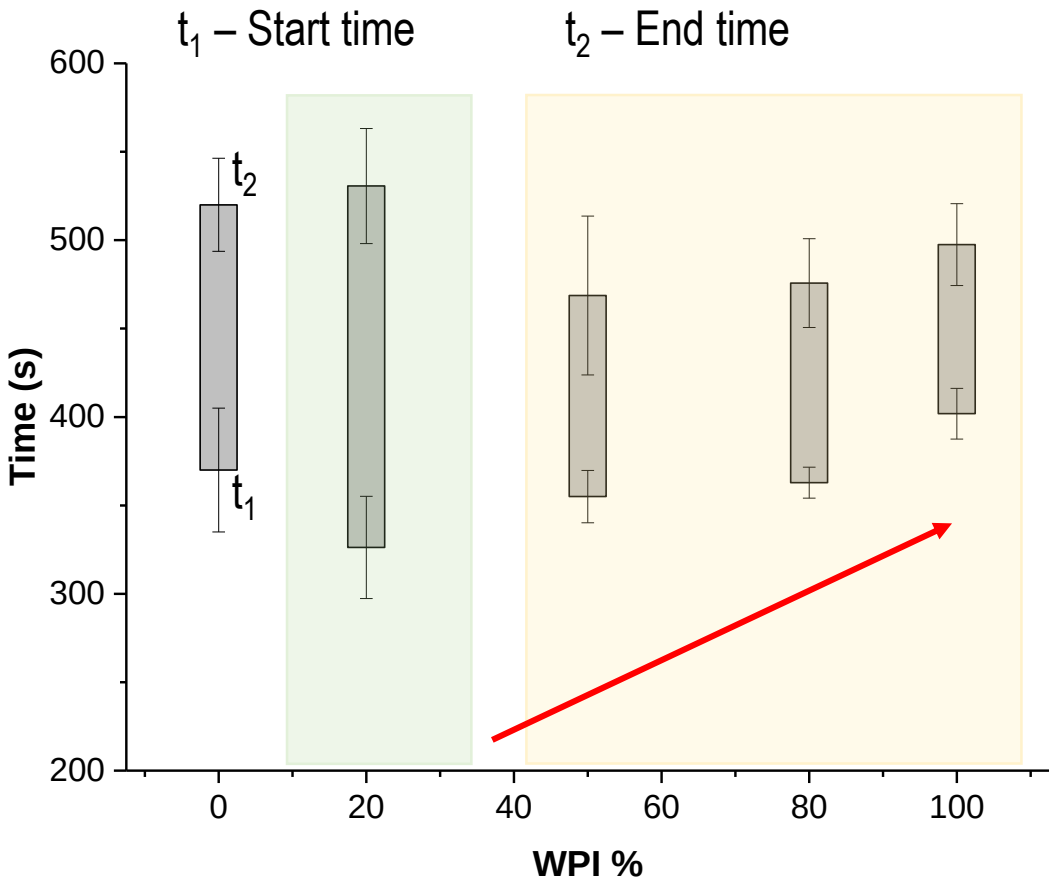


Visualization of droplet profile



Stage II is crucial to understand the particle formation

Overview of the Stage II (Sol-gel transition)

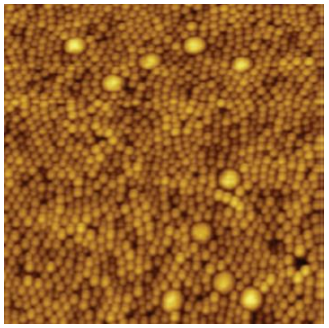


- Stage II earlier in mixes

  NPC retain water

- WPI≥ 50%: Stage II almost constant

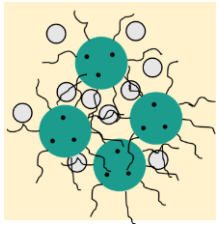
THE SKIN IS MORE RIGID(SMALL-ON-TOP)



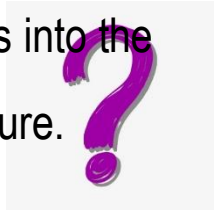
Trueman R E, 2012, *Langmuir, 28*(7), 3420-3428.
Trueman R E, 2012, Journal of Colloid & Interface Science, 2012, 377(1):207-212.
Lanotte et al., 2018, Colloids and Surfaces,20, 0927-7757
Fortini A, Journal Physical Review Letters, 2017

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

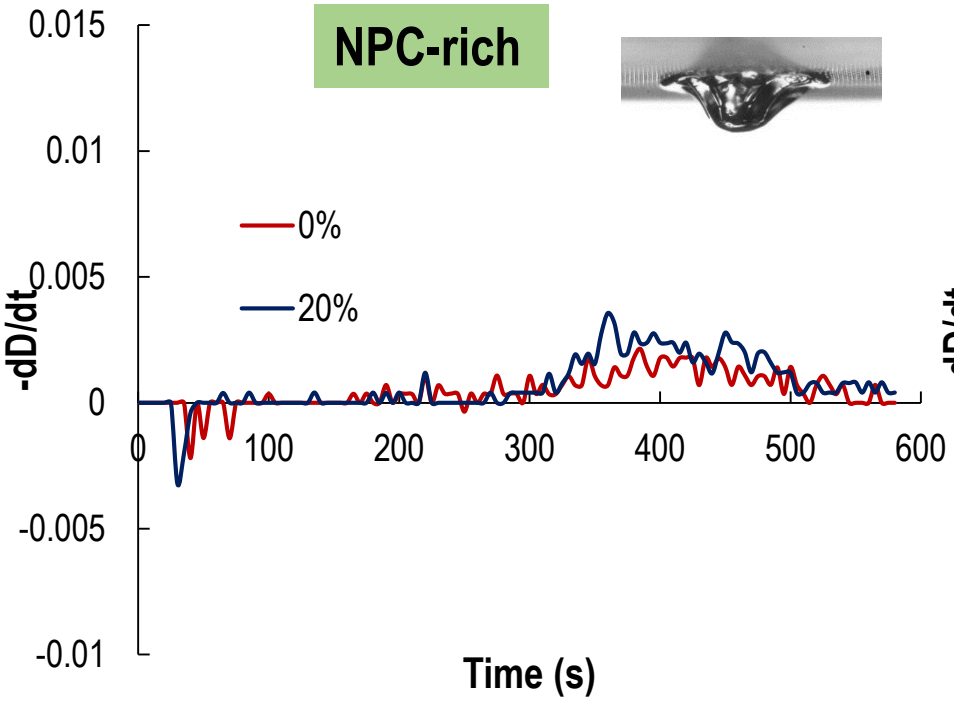
STAGE II = DELAMINATION + SKIN ELASTIC RESPONSE

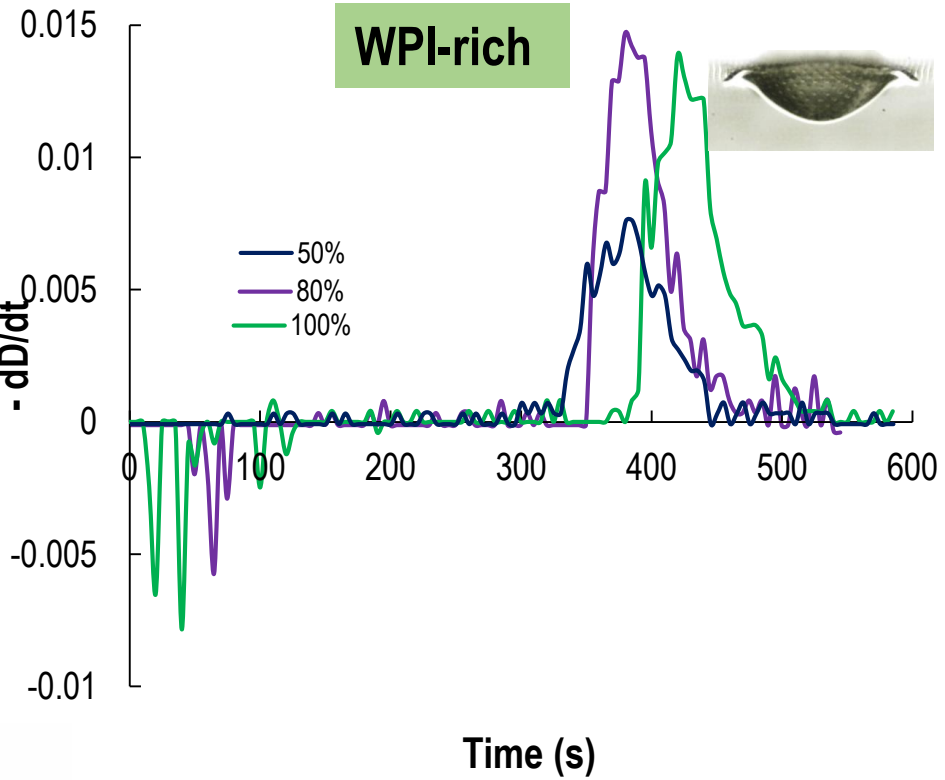


WPI enters into the NPC structure.



The delamination of WPI/NPC mixture samples





NPC: no delamination

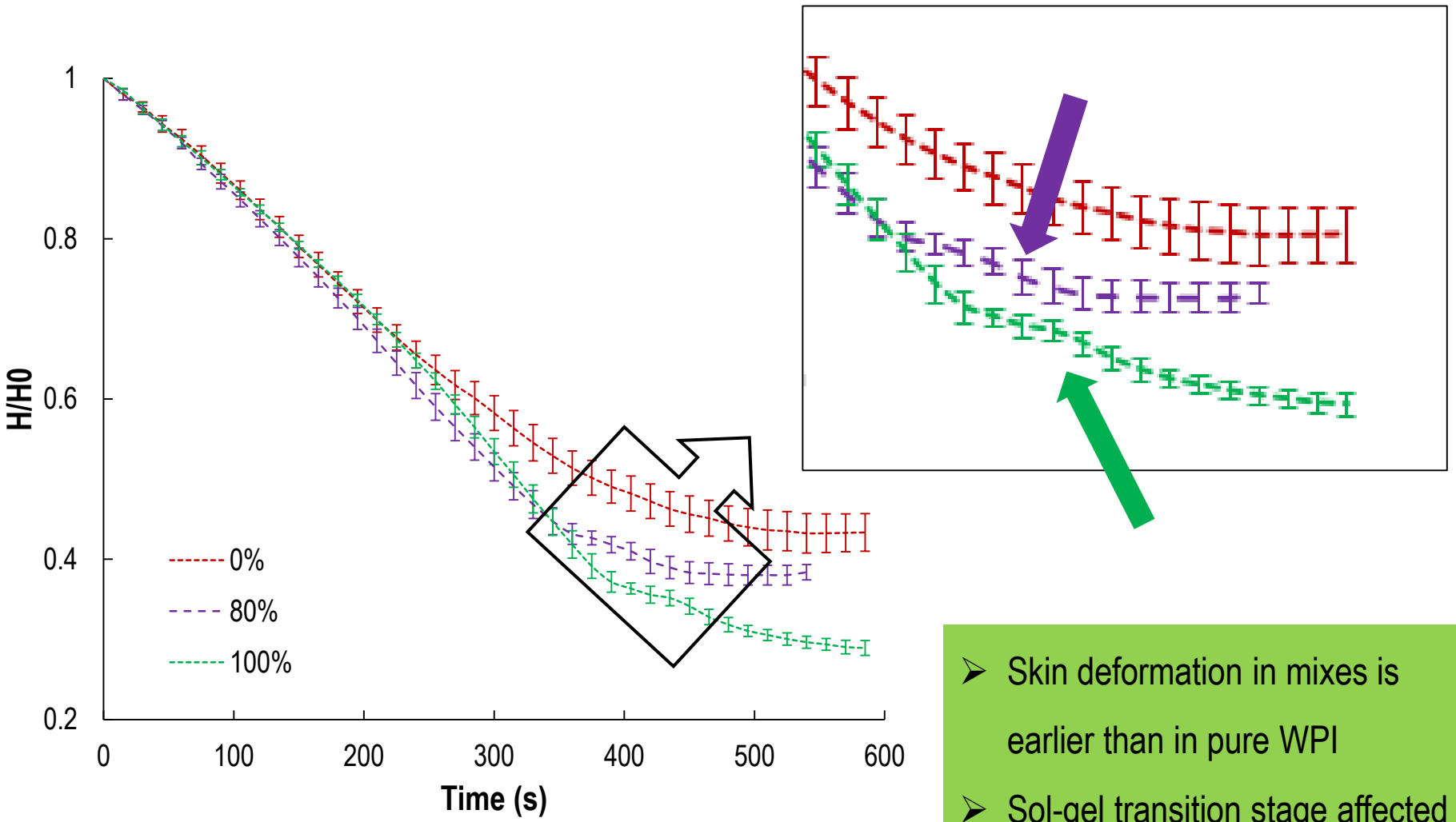
WPI: stronger delamination

Mixing?

Few NPC promote delamination
Massive NPC weaker delamination

➢ Delamination affect by WPI%

The effect of $WPI\%_R$ 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
- Sadek et al., 2014, Dairy Sci Technol, 95, 771-794
- Sadek et al., 2015, Food Hydrocolloids, 48, 8-16
- Sadek et al., 2016, Food Hydrocolloids, 52, 161-166
- 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