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## Drying research : from physical and biological mechanisms to breakthrough innovation

Cécile Le Floch-Fouéré, Luca Lanotte, Song Huang, Céline Sadek, Maheshchandra H Patil, Gwénaél Jan, Gaëlle Tanguy, Eoin G Murphy, Xiao Dong Chen, Romain Jeantet

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# Drying research

*From physical and biological mechanisms to  
breakthrough innovation*

Cécile Le Floch-Fouéré, Luca Lanotte, Song Huang, Céline Sadek, Ming Yu, Mahesh Patil, Gwénael Jan, Gaëlle Tanguy, Eoin Murphy, Xiao Dong Chen, Romain Jeantet

**STLO : Science et Technologie du Lait et de l'Œuf**  
**UMR 1253 Rennes**



# > Context , Research topics , Strategy

- ❑ Massive growth of Infant milk formula (IMF) market
- ❑ Controlled properties, incorporation of live probiotics
- ❑ Environmental and costs concern

Understand the particle formation mechanisms

Identify the key parameters that rule the powder properties and evolution

Explore new technological concepts for technological breakthrough innovation

Consider simplified & controlled models (dairy colloids, bacteria)

Observe the phenomenon at different scales to make the study possible

Combine disciplines: from biology to soft matter and chemical engineering

Partnership to feed the scientific questions and identify technological outputs

1.

- ***Exploring particle formation to control IMF properties***

2.

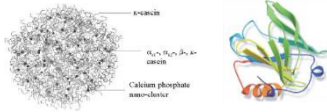
- ***Triggering the protection mechanisms to maximize survival of bacteria***

3.

- ***Redesigning the process for the production of whey/permeate powders***

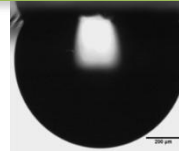
# ➤ Strategy - Study of the drying process on multi-scales

## Milk colloids



- Whey protein isolates (WPI)
- Micellar casein (MC)
- Single or mixed together

## Single droplet 3D / 2D



### PARTICLE FORMATION

- **Control and study** the drying kinetics
- **Record *in situ*** deformation

## Coupling methods

- Mass balance
- Microscopy
- Rheology

## Mono-disperse droplets



### PARTICLES PROPERTIES

- **Control** drying history
- **Get** homogenous samples
- **Analyze** physical properties

## Spraying cone of droplets



### SCALE UP

- **Validate** on an industrial scale
- **Control** powder properties

# Protein signature in the course of drying

*Langmuir* **29** (2013) 15606 - 15613

*Drying Technol* **32** (2014) 1540 - 1551

*Food Hydrocolloids* **48** (2015) 8 - 16

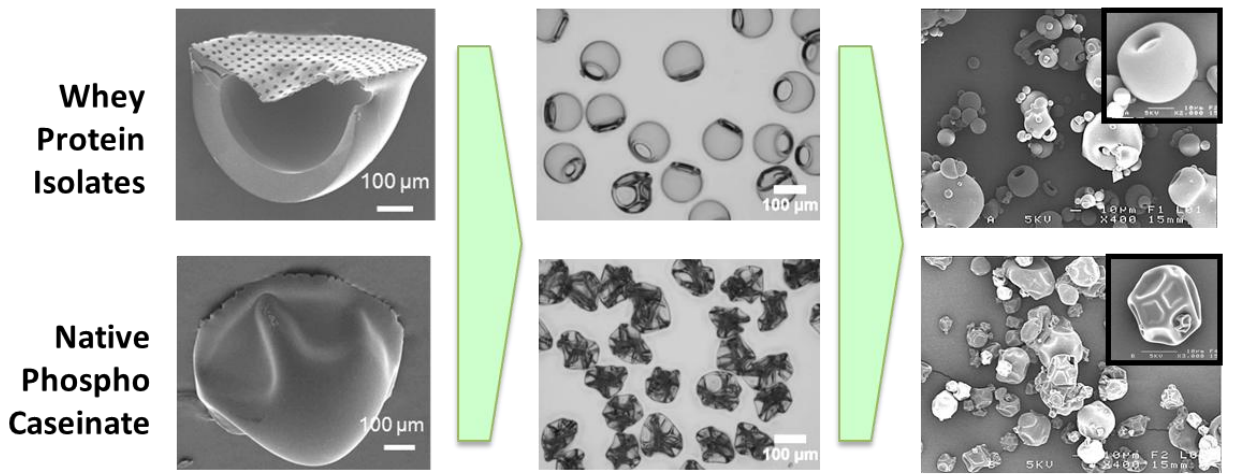
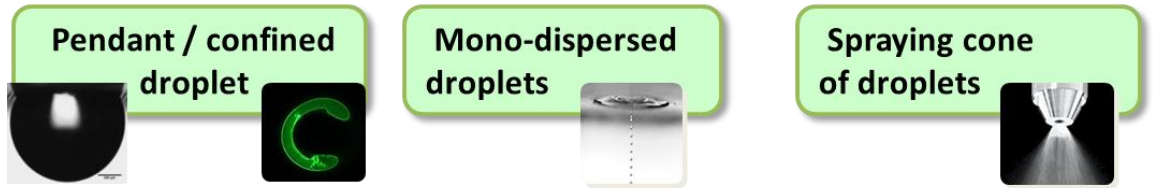
*Food Hydrocolloids* **52** (2016) 161 -166

*Colloids and Surfaces A* **553** (2018) 20-27

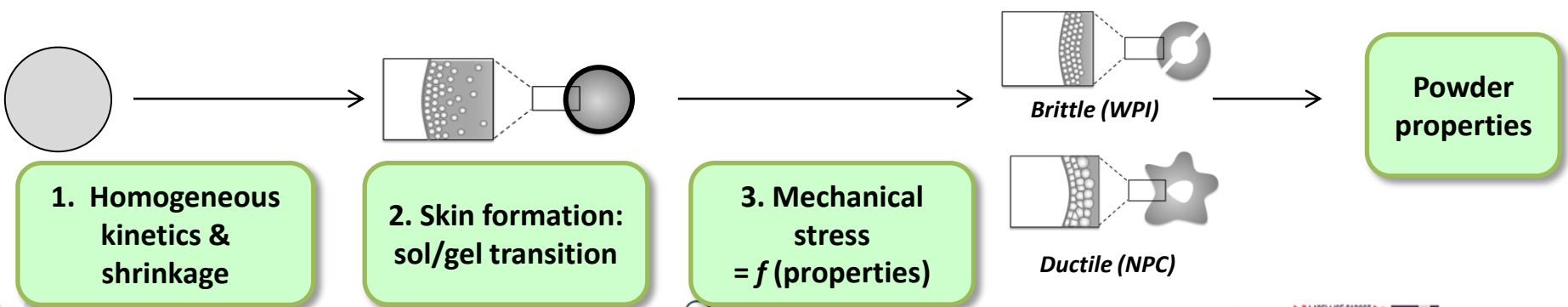
*Colloids and Surfaces A* **620** (2021) 126560

*Foods* **11** (2022) 562

Specific signatures of WP and MC proteins governing the particle formation / shape and properties, regardless of the drying kinetics



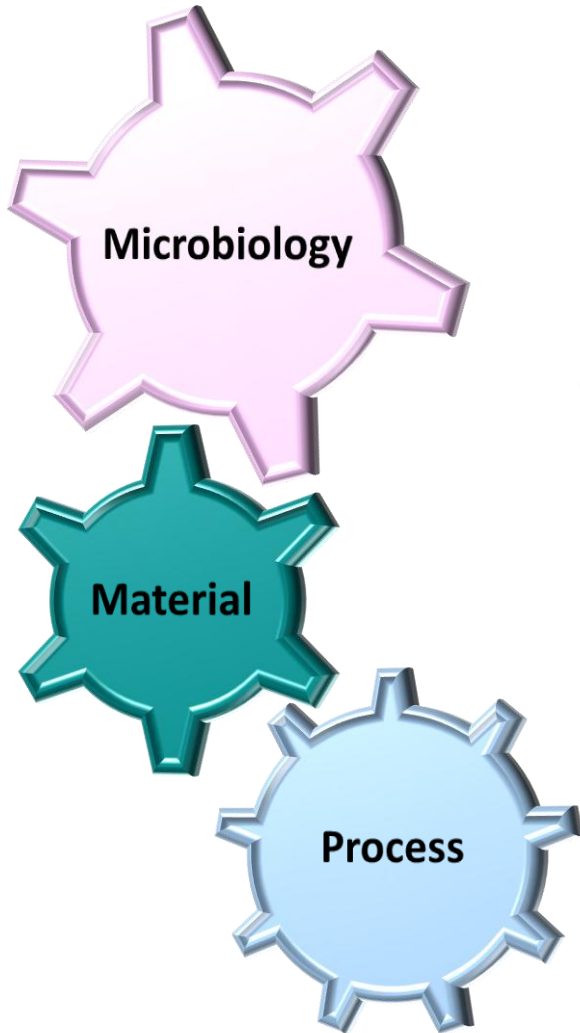
Drying kinetics	10 min	10 s	
Particle Size	500 μm	140 μm	42-56 μm
Drying temperature	20 ° C	190 ° C	210 ° C



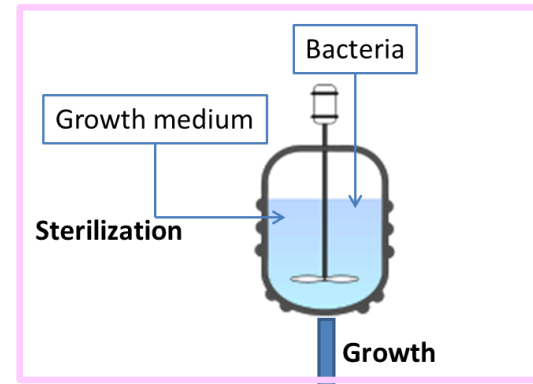
2.

- ***Triggering the protection mechanisms to maximize survival of bacteria***

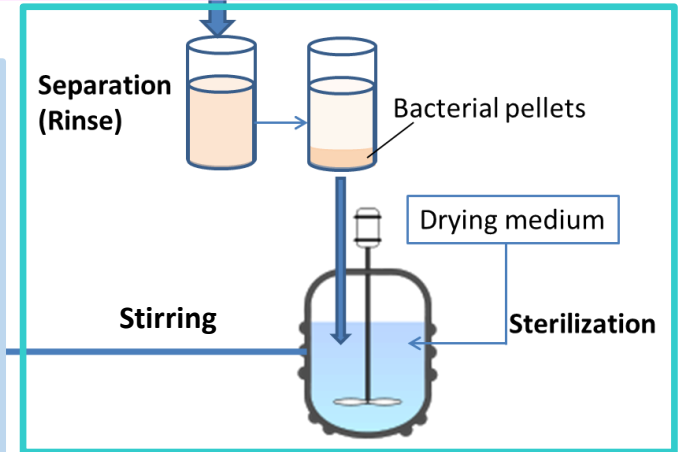
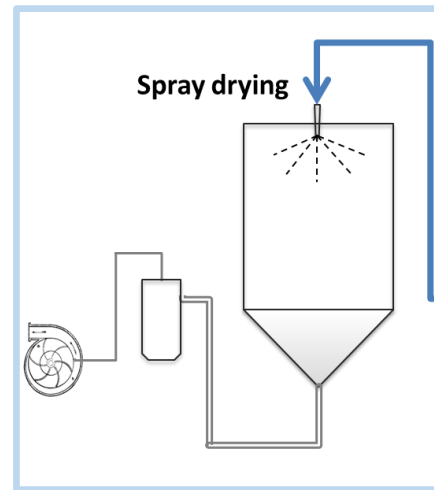
# ➤ Strategies in probiotics drying research



Optimize/moderate drying conditions: multistage, belt, etc.



Resistant strain selection, Cross-protection via sublethal stresses, etc.



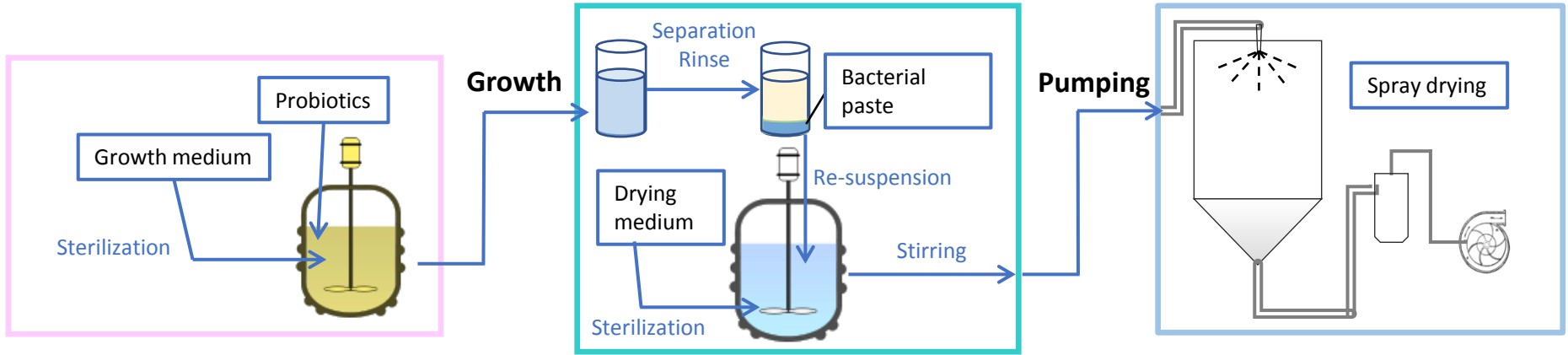
Protective food grade constituents: Carbohydrates, proteins, polymers, minerals



Coupling strategies to improve probiotics viability?



# > A coupled approach for a novel process



Cross-protection

Sublethal osmotic

Stress Tolerance

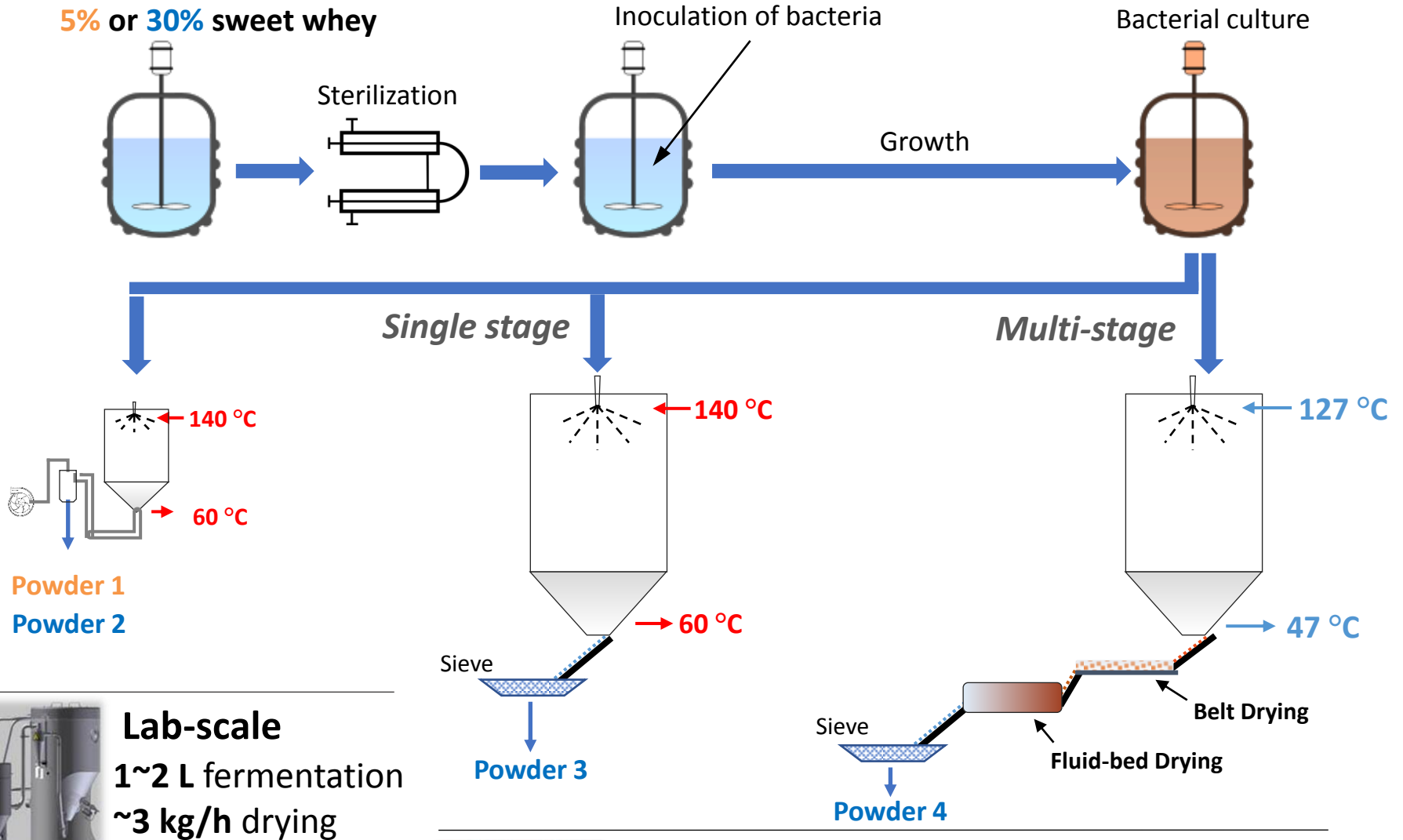
Concentrated  
2-in-1 (Growth  
& Drying)  
Medium

Multi-stage drying

Pre-concentration

Lower  $\theta$  / Energy savings

# ➤ Drying bacteria at different scales



## Lab-scale

1~2 L fermentation  
~3 kg/h drying



## Pilot-scale BIONOV

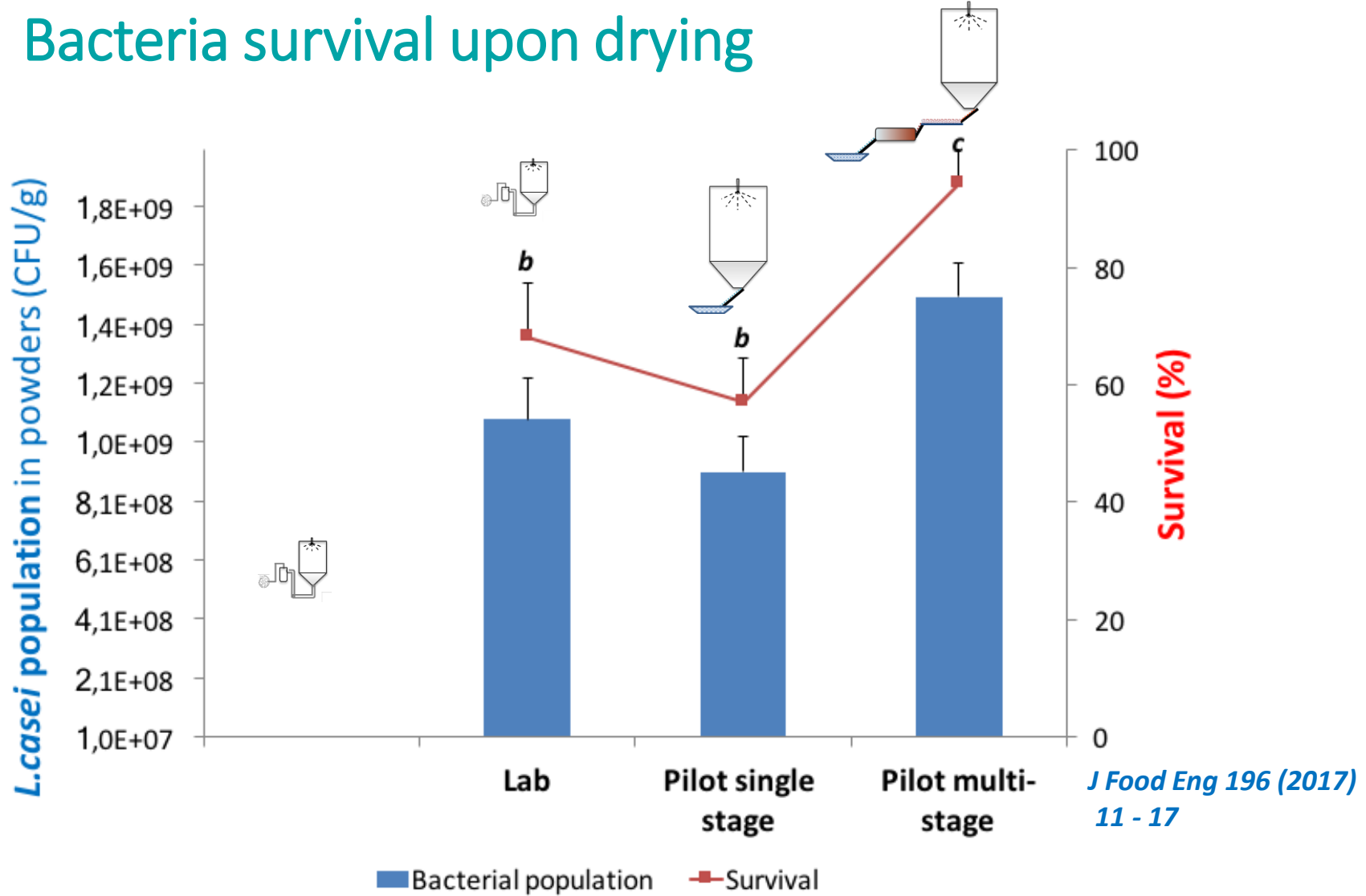
500 L fermentation  
~100 kg/h drying

*J Food Eng 196 (2017) 11 - 17*

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# ➤ Bacteria survival upon drying

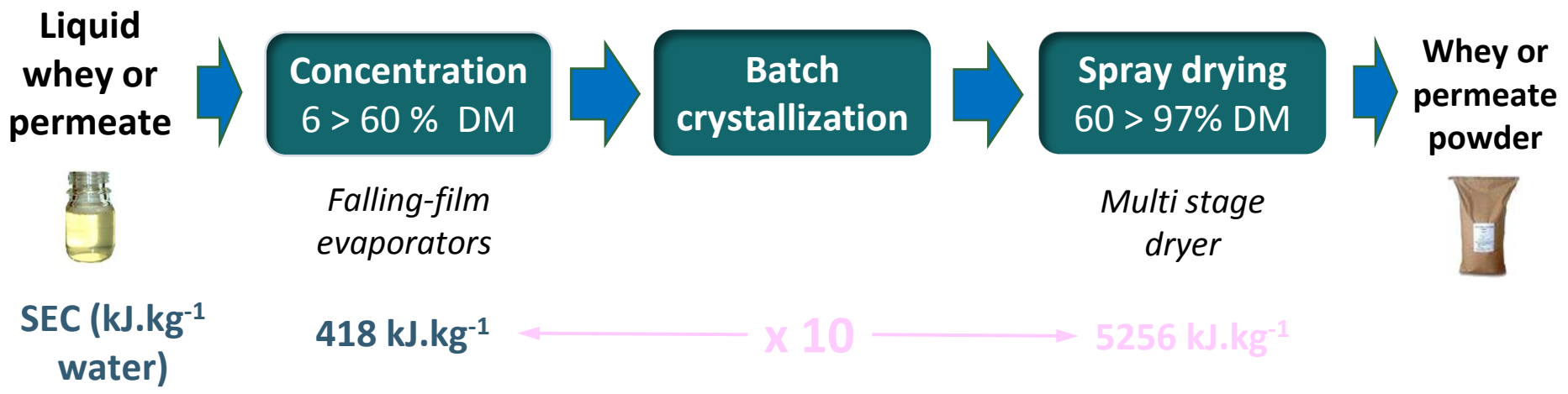


Acquired cross protection with multi stage scheme provides 100% survival  
 ⇒ Patented process EP 15 306465.4 - 1357

3.

- *Redesigning the process for the production of whey/permeate powders*

# ➤ Current bottlenecks in whey/permeate powder production



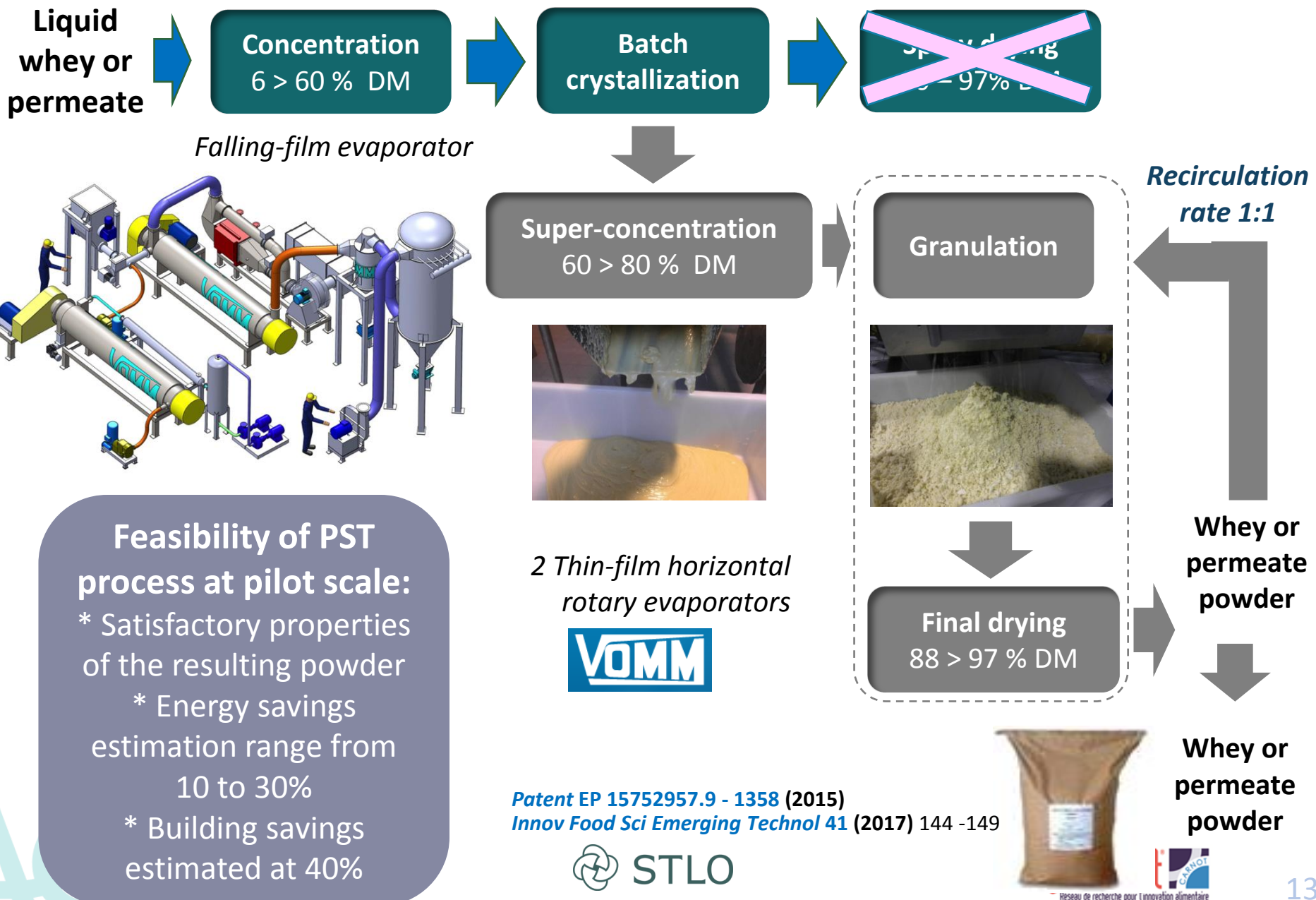
❓ concentrate DM, but limiting viscosity / pumping and spraying

55% of the overall energy for less than 10% of the water removed



Innovative process based on thin-film rotary evaporator where viscosity is controlled by a vigorous mechanical treatment that maintains a fluid flowing state at high DM

# ➤ Patented PST : a new process for whey/permeate powder



**Feasibility of PST process at pilot scale:**

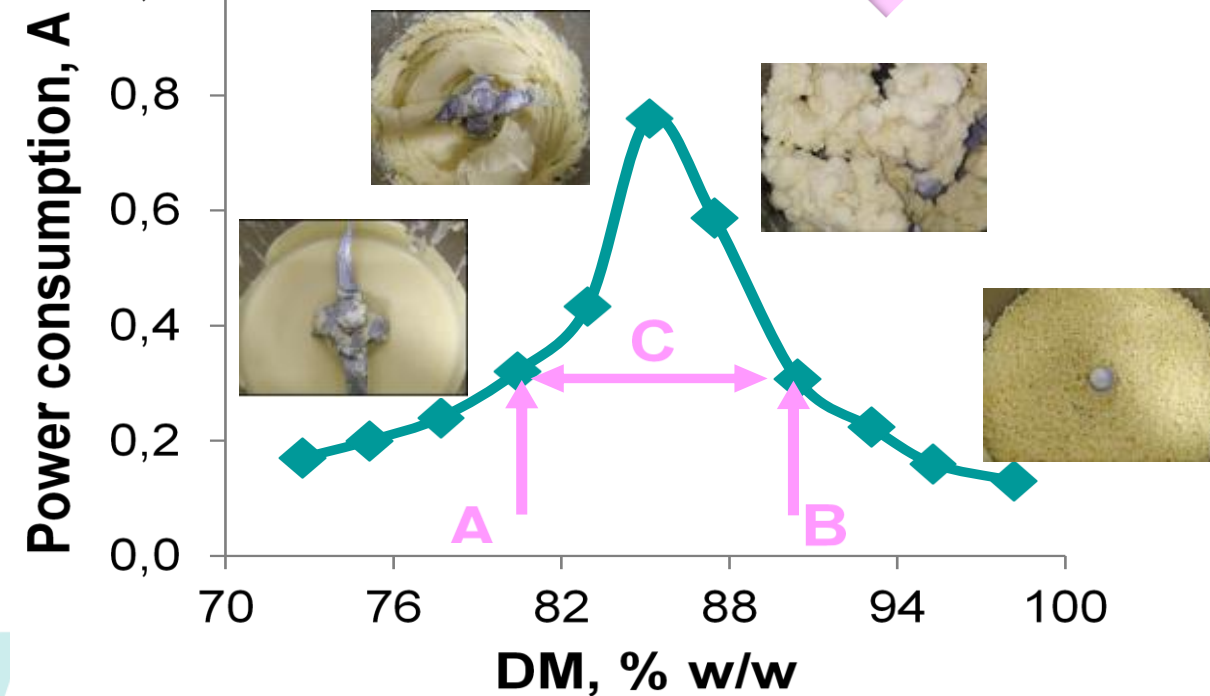
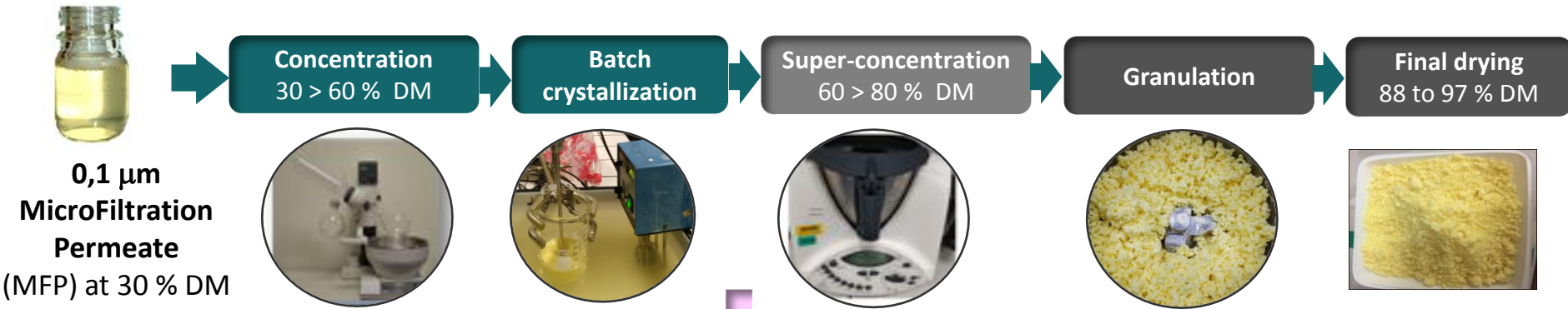
- \* Satisfactory properties of the resulting powder
- \* Energy savings estimation range from 10 to 30%
- \* Building savings estimated at 40%

Patent EP 15752957.9 - 1358 (2015)  
 Innov Food Sci Emerging Technol 41 (2017) 144 -149



# ➤ Limiting factors of superconcentration & granulation process

Development of a lab-scale model to mimic the PST process



A reliable protocol to identify,  
\* crucial parameters of the superconcentration-granulation process  
\* the influence of composition on product-process interactions

A: maximum surconcentration; B: minimum recirculation rate for granulation; C: Highly cohesive phase

# ➤ Conclusion and perspectives

## Take-home messages

- Colloid properties conditions the skin formation and properties
- Tuning compatible solutes accumulation to enhance bacterial survival
- PST process control relies on cohesive phase understanding

## Extensive work on IMF formulation is needed in future

- Process determines powder properties
- Conditions particle intrinsic features, then powder properties
- Enhances probiotics survival during drying and in the dry state

## Research strategy to overcome industry challenges

- Address simultaneously hygienic / nutritional / environmental issues
- Identifying the mechanisms at small scale, scale up needed
- Multidisciplinary approach is mandatory: physics / biology / medical



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THANK YOU FOR YOUR ATTENTION



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L'ABELLISÉ CARROT  
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Réseau de recherche pour l'innovation alimentaire