



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.

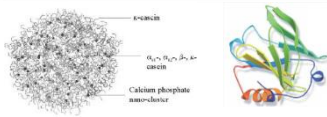
- ***Triggering the protection mechanisms to maximize survival of bacteria***

3.

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

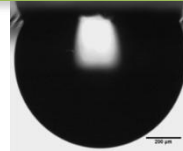
➤ Strategy - Study of the drying process on multi-scales

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

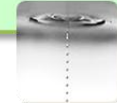
Foods **11** (2022) 562

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

Pendant / confined
droplet



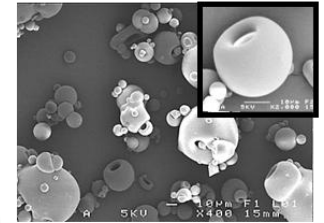
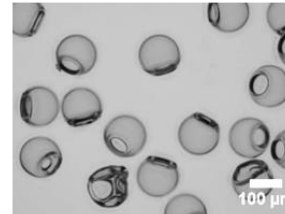
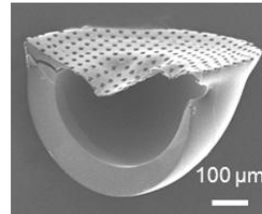
Mono-dispersed
droplets



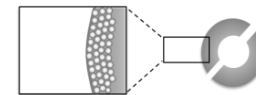
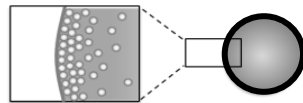
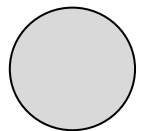
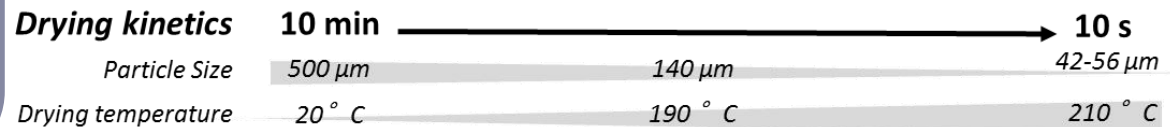
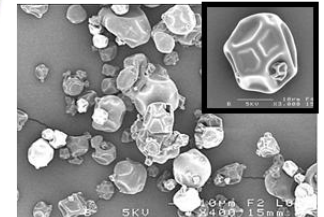
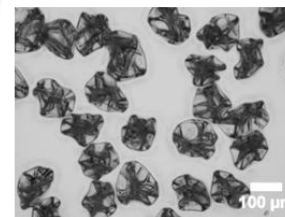
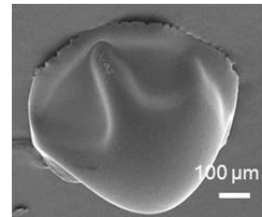
Spraying cone
of droplets



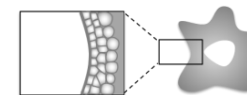
Whey
Protein
Isolates



Native
Phospho
Caseinate



Brittle (WPI)



Ductile (NPC)

Powder
properties

1. Homogeneous
kinetics &
shrinkage

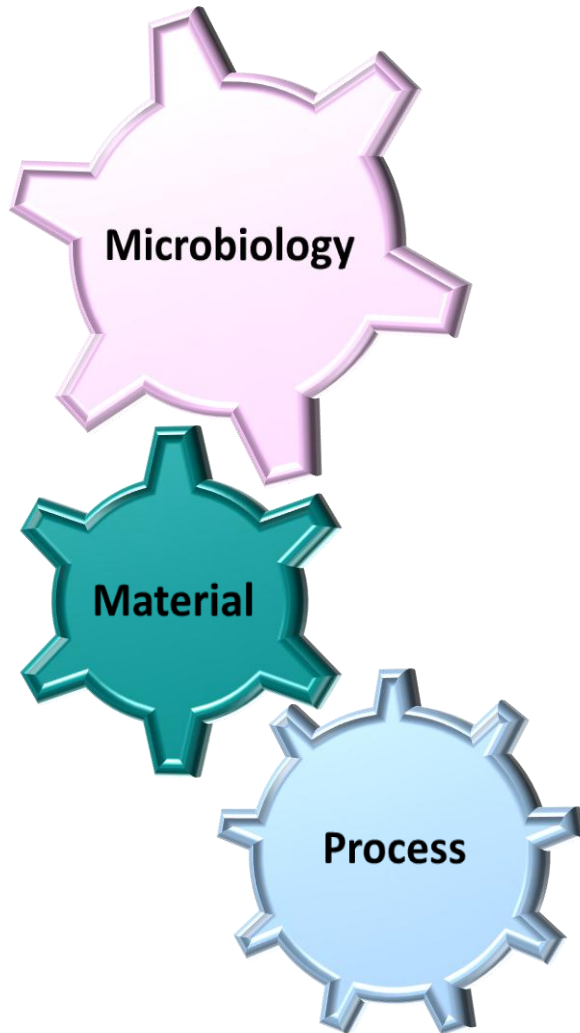
2. Skin formation:
sol/gel transition

3. Mechanical
stress
= f (properties)

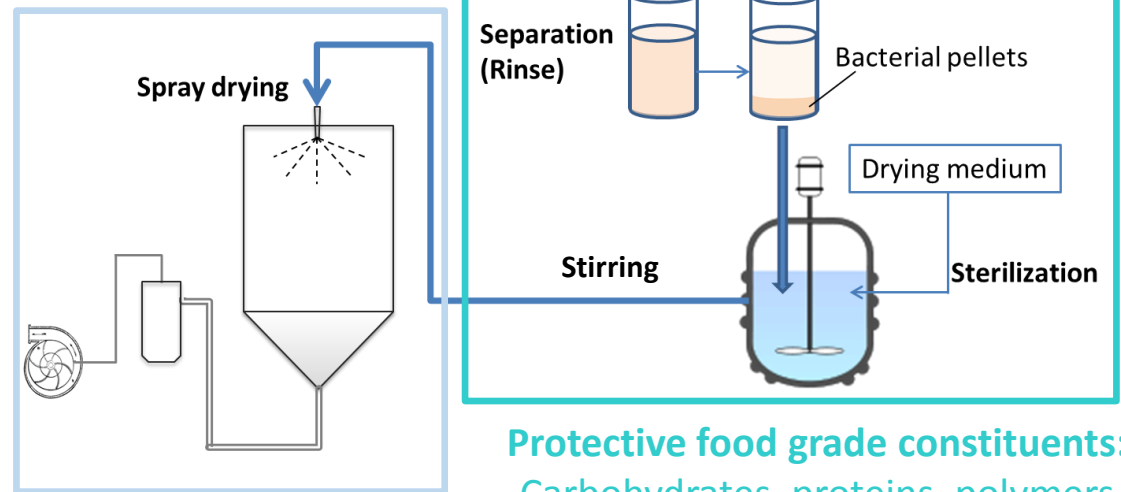
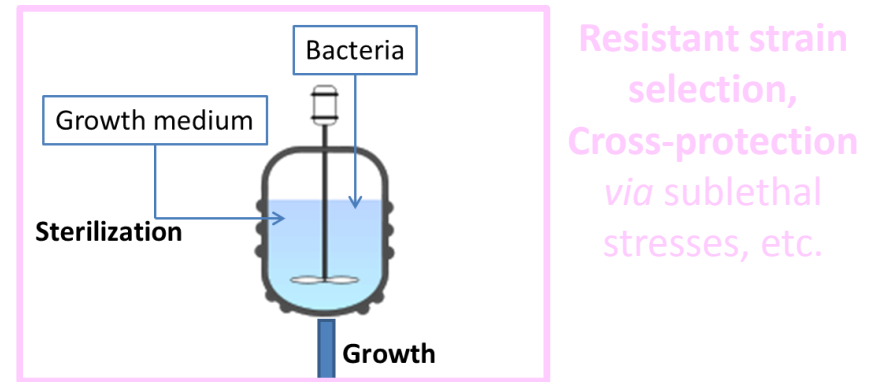
2.

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

➤ Strategies in probiotics drying research



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



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



Coupling strategies to improve probiotics viability?

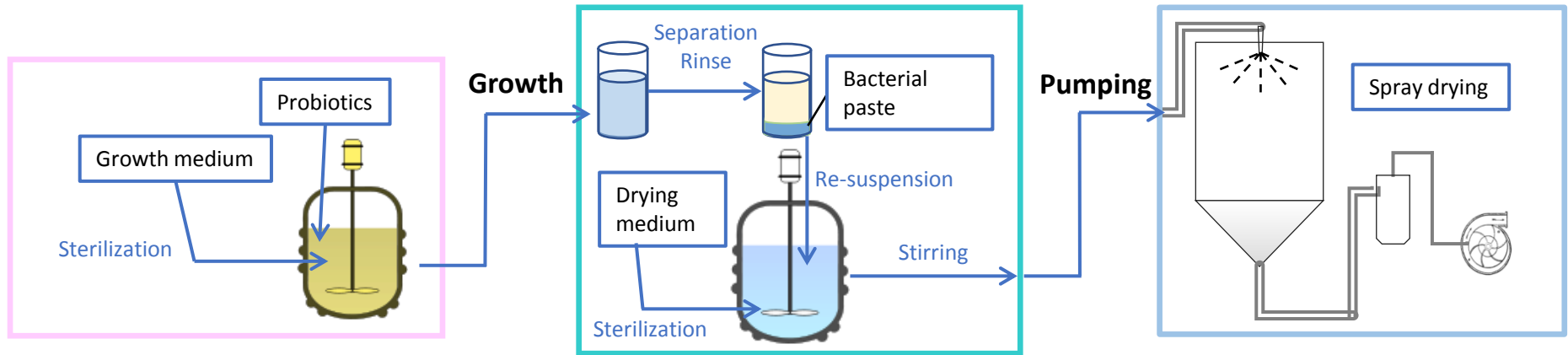
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Réseau de recherche pour l'innovation alimentaire

> 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 θ / Energy savings

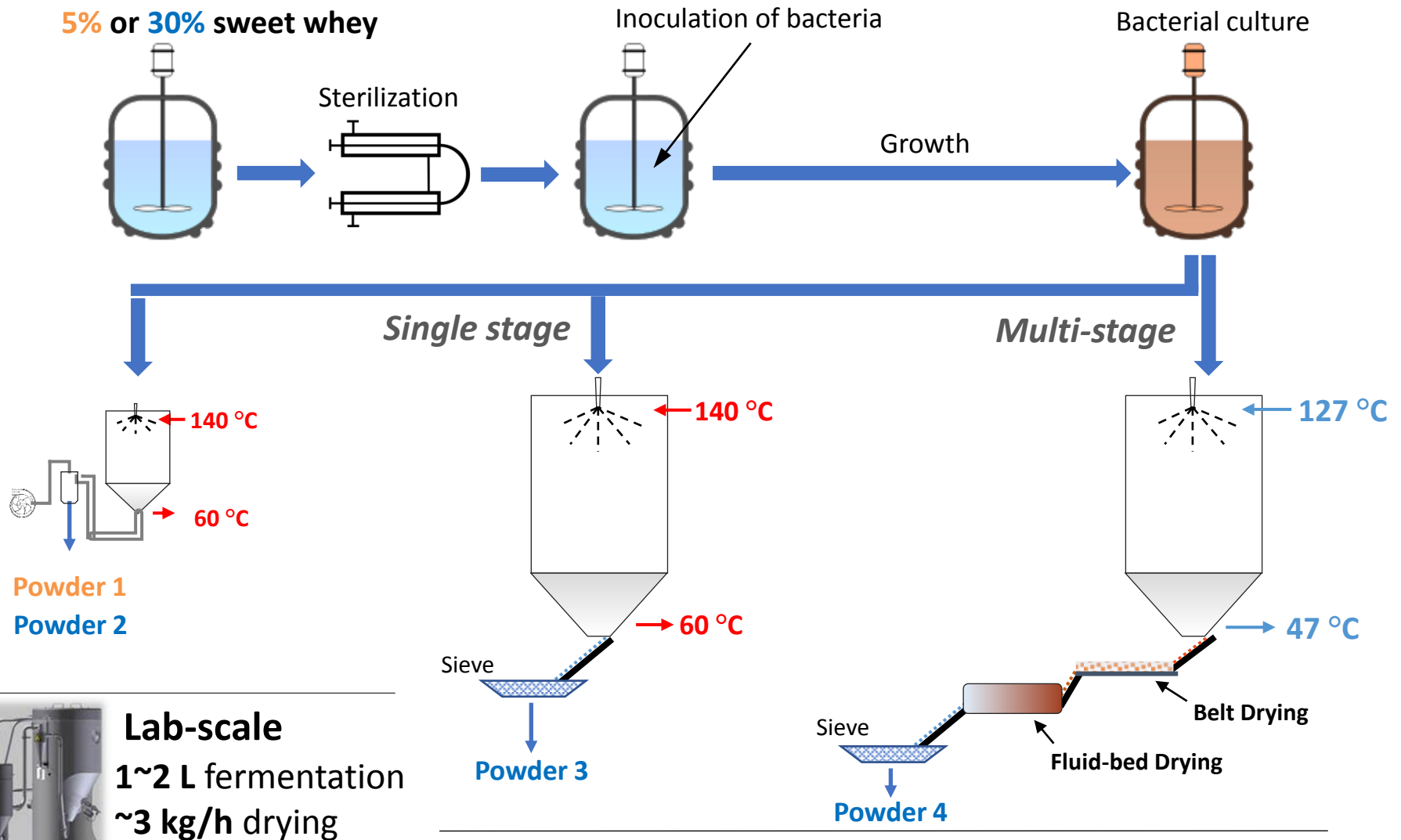
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➤ Drying bacteria at different scales



Lab-scale

1~2 L fermentation
~3 kg/h drying

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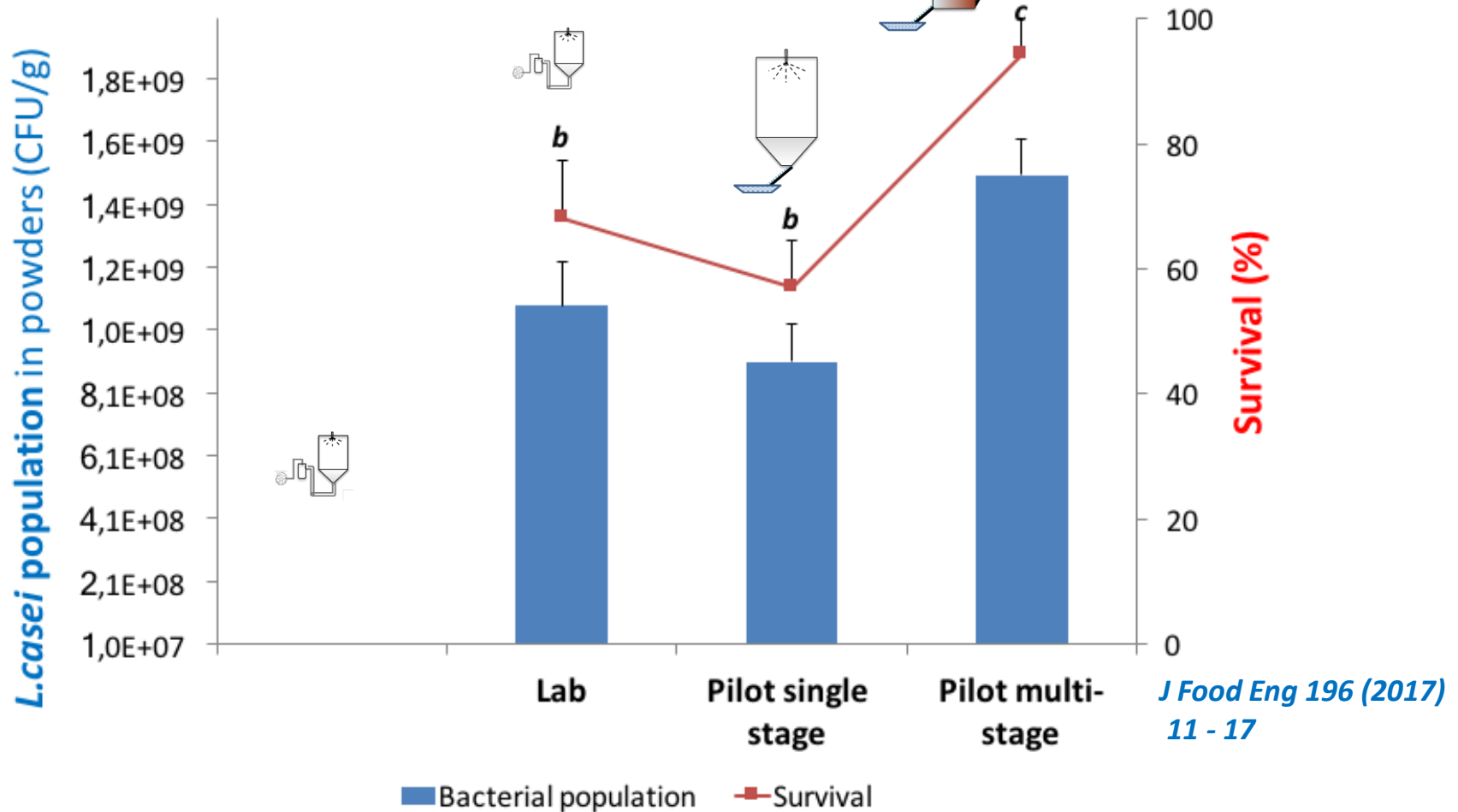


Pilot-scale BIONOV

500 L fermentation
~100 kg/h drying

J Food Eng 196 (2017) 11 - 17

➤ Bacteria survival upon drying

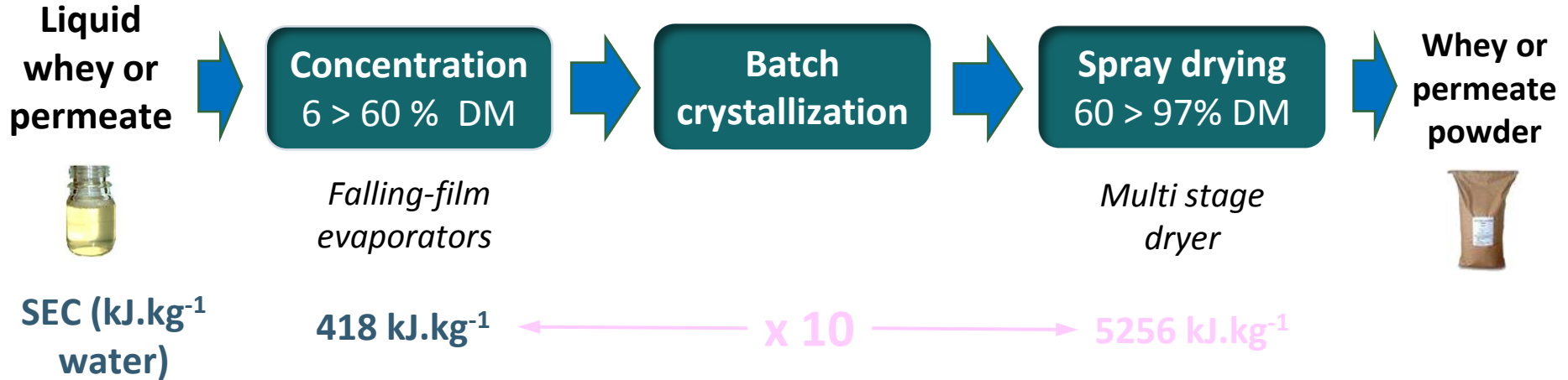


Acquired cross protection with multi stage scheme provides 100% survival
⇒ Patented process EP 15 306465.4 - 1357

3.

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

➤ Current bottlenecks in whey/permeate powder production



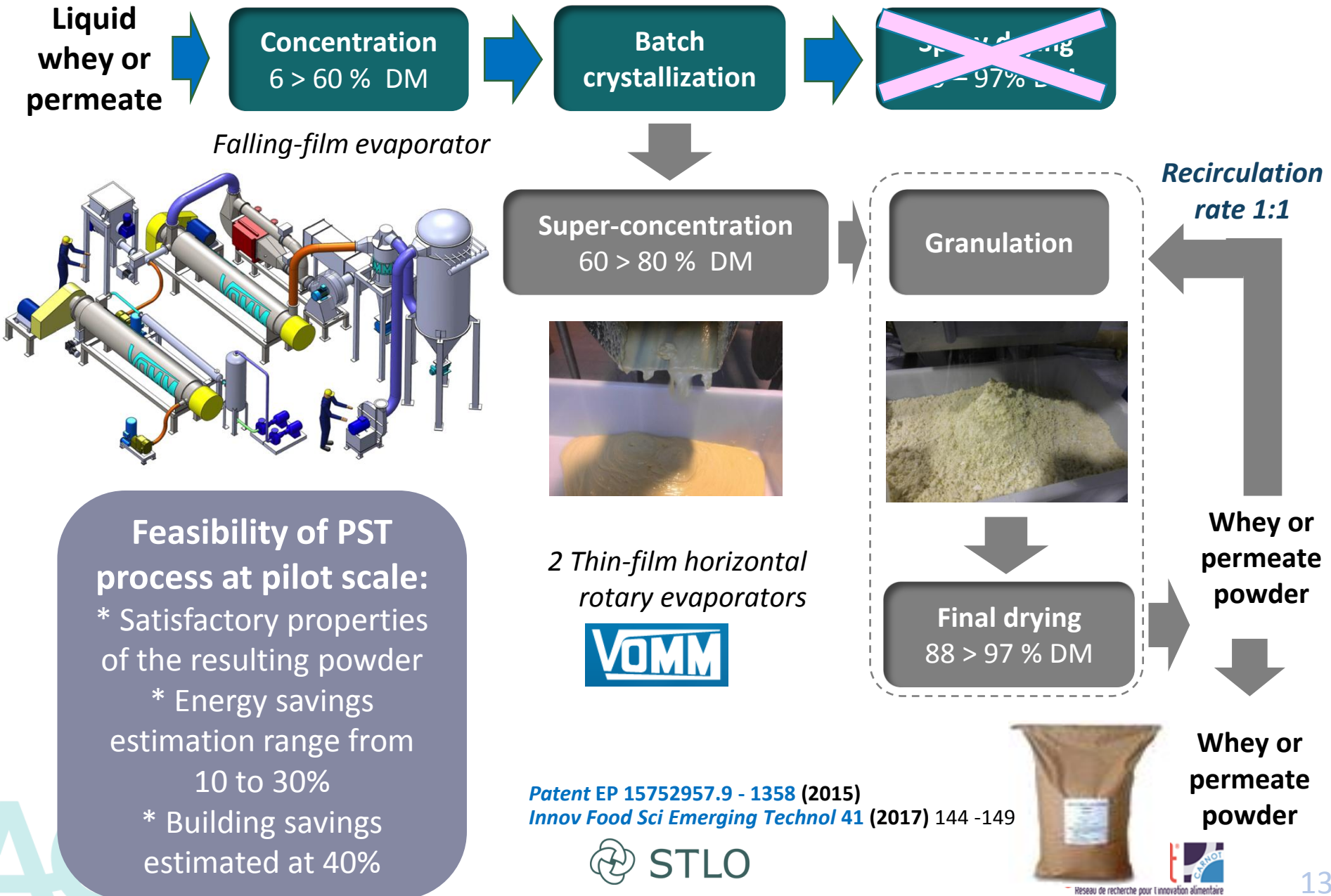
❓ concentrate DM, but limiting viscosity / pumping and spraying

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



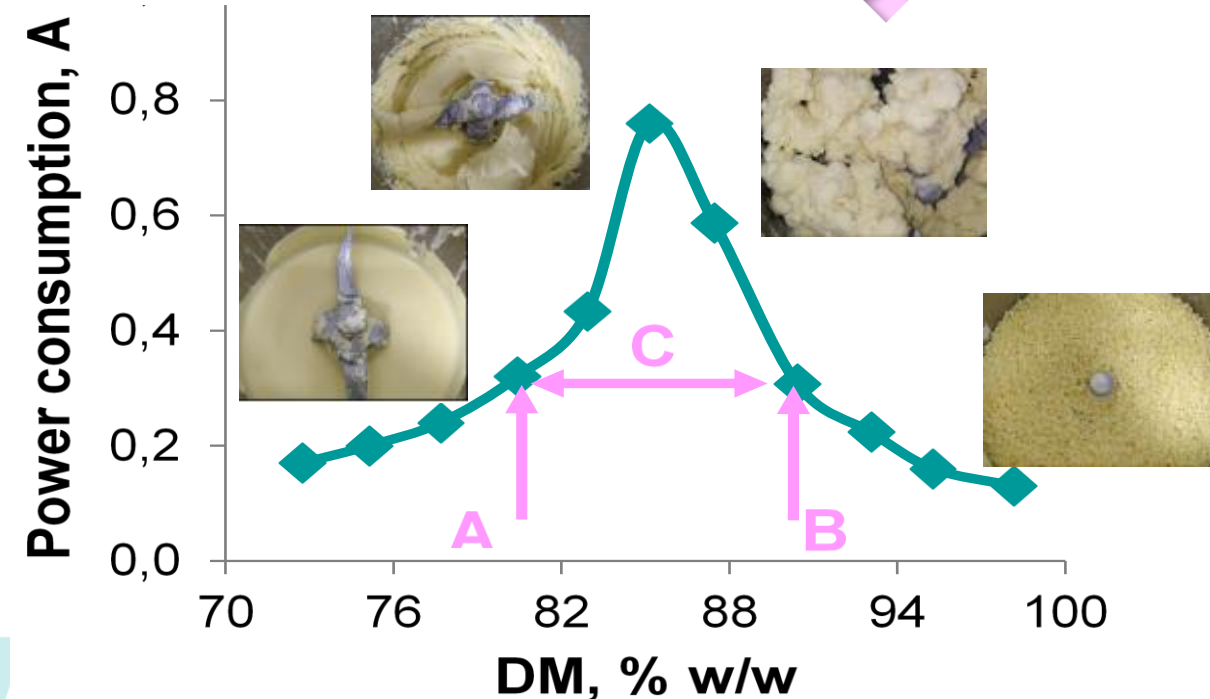
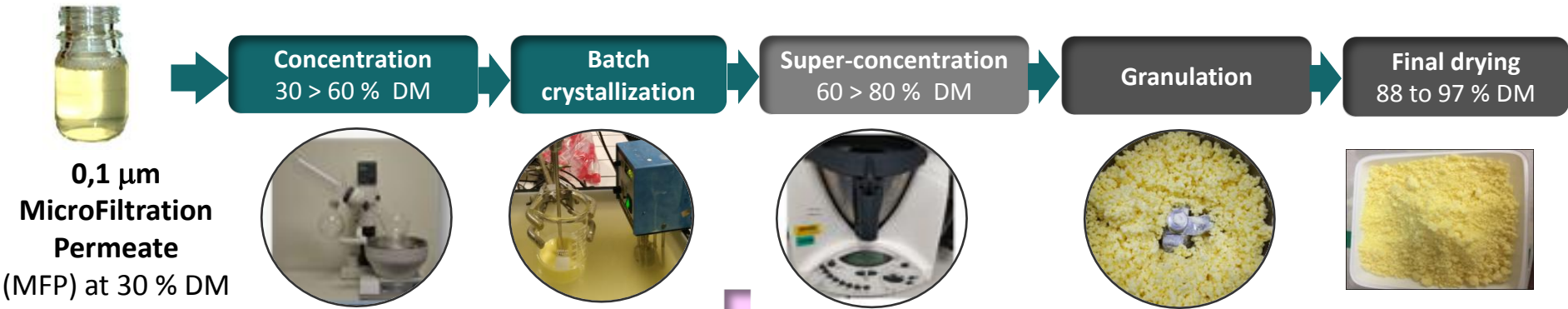
Innovative process based on thin-film rotary evaporator where viscosity is controlled by a vigorous mechanical treatment that maintains a fluid flowing state at high DM

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



➤ 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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