



HAL
open science

Drying research From physical and biological mechanisms to breakthrough innovation

Luca Lanotte, Romain Jeantet

► **To cite this version:**

Luca Lanotte, Romain Jeantet. Drying research From physical and biological mechanisms to breakthrough innovation. STLOpendays, Institut National de Recherche Agronomique (INRA). UMR UMR INRA / AgroCampus Rennes : Science et Technologie du Lait et de l'uf (1253)., Mar 2019, Rennes, France. hal-02097218

HAL Id: hal-02097218

<https://hal.science/hal-02097218>

Submitted on 5 Jun 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

AGRO
CAMPUS
OUEST



Drying research

From physical and biological mechanisms to breakthrough innovation



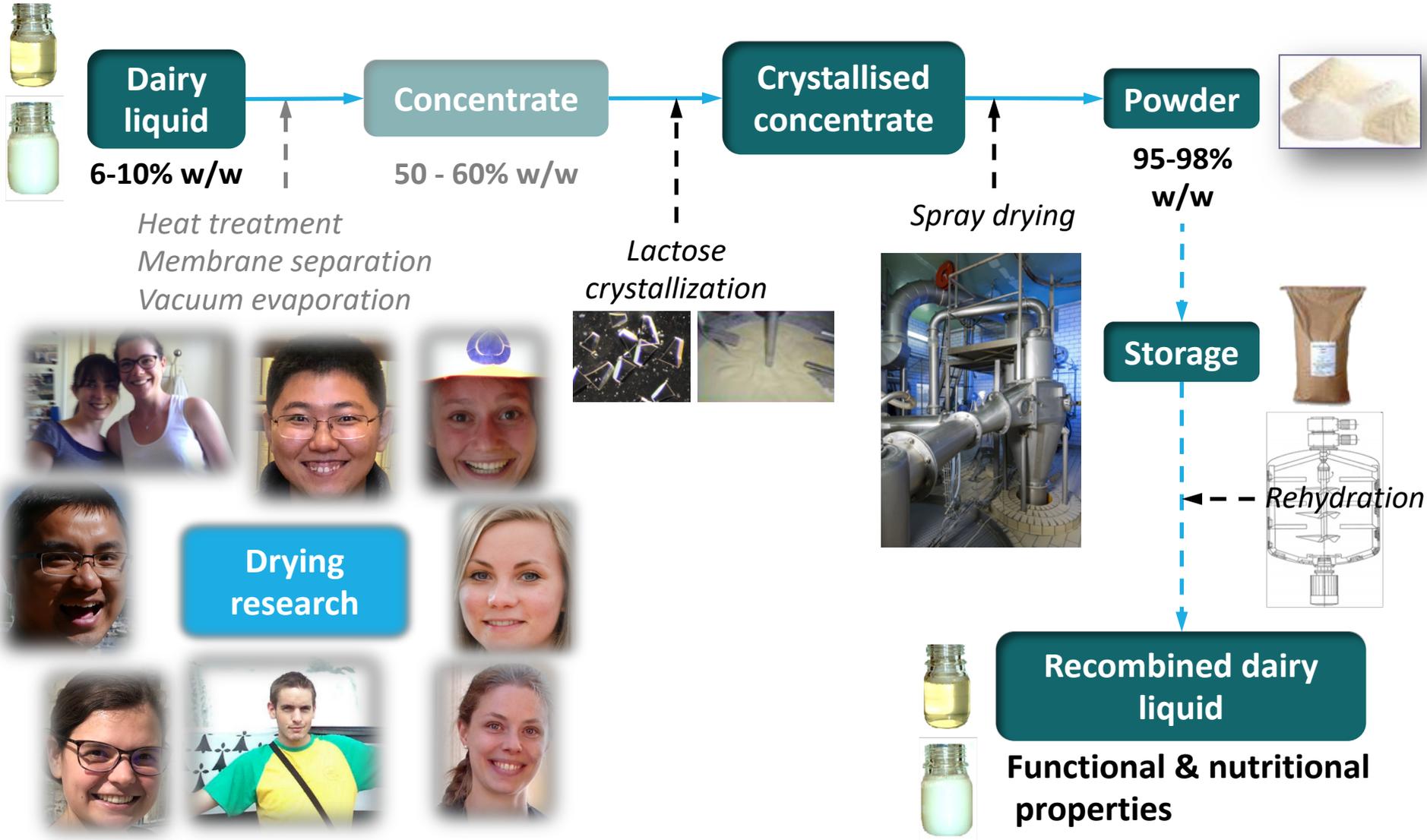
STLOpen Days
19-21 March 2019



Luca Lanotte & Romain Jeantet



Concentration, drying and rehydration of dairy products



Drying research



Context , Research topics , Strategy

- ❑ Massive growth of Infant milk formula (IMF) / protein isolate 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.

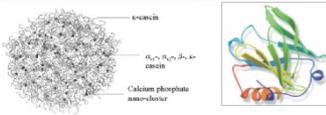
Triggering the protection mechanisms to maximize survival of bacteria

3.

Redesigning the process for the production of whey/permeate powders

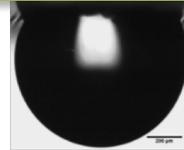
Strategy - Study of the drying process on multi-scales

Milk colloids



- Whey protein (WP)
- 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

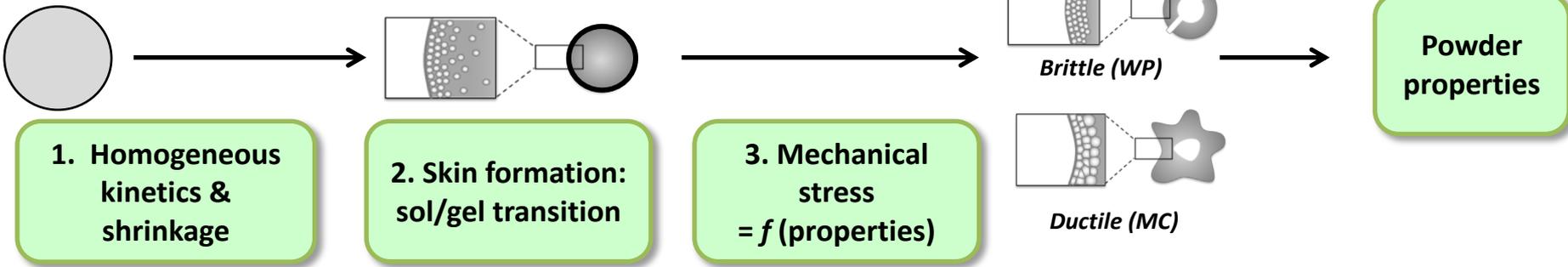
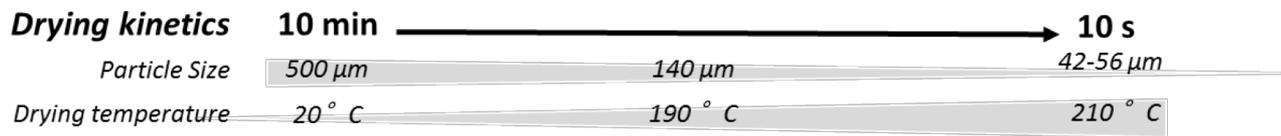
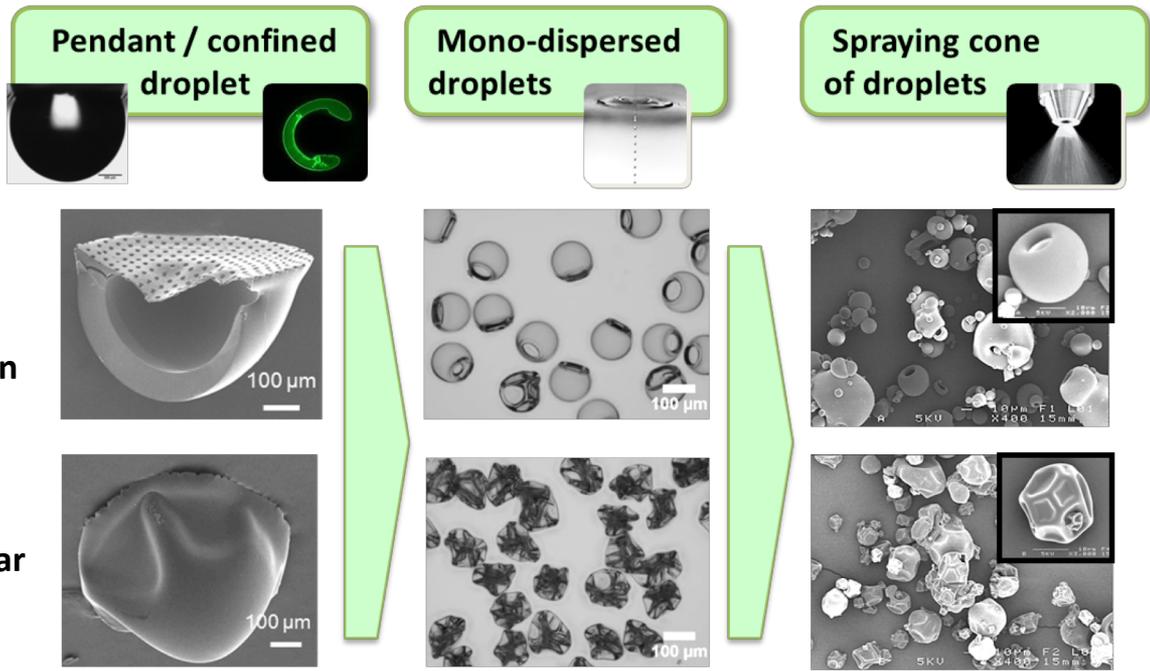
Langmuir 29 (2013) 15606 - 15613

Drying Technol 32 (2014) 1540 - 1551

Food Hydrocolloids 48 (2015) 8 - 16

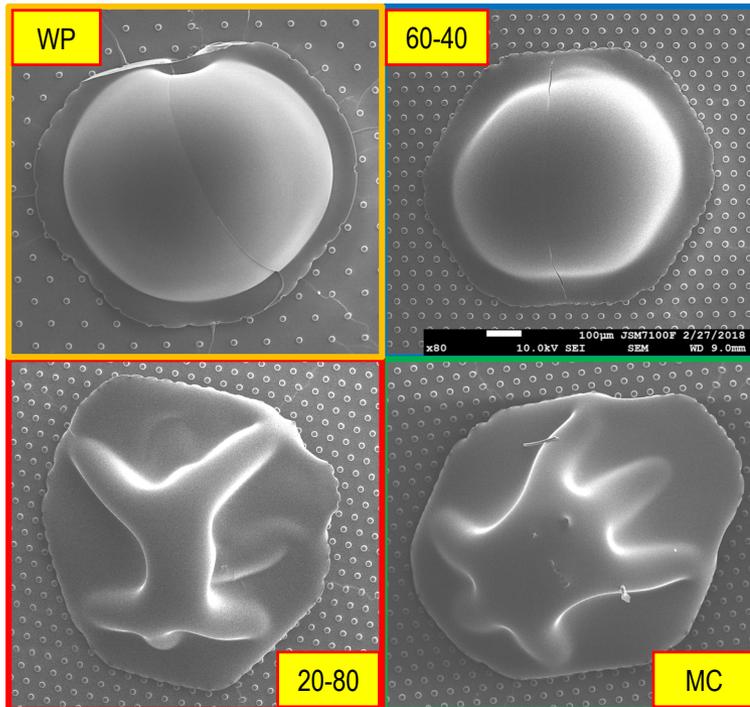
Food Hydrocolloids 52 (2016) 161 -166

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

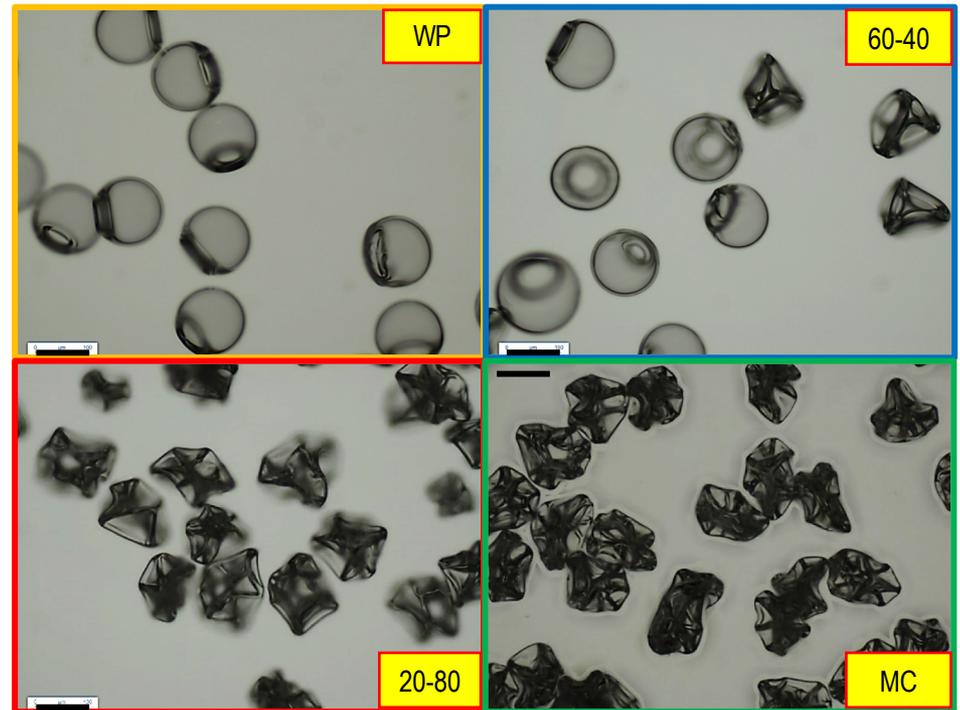


Protein signature : the case of protein mixes

Single pendant droplet Scanning Electron Microscopy (SEM)



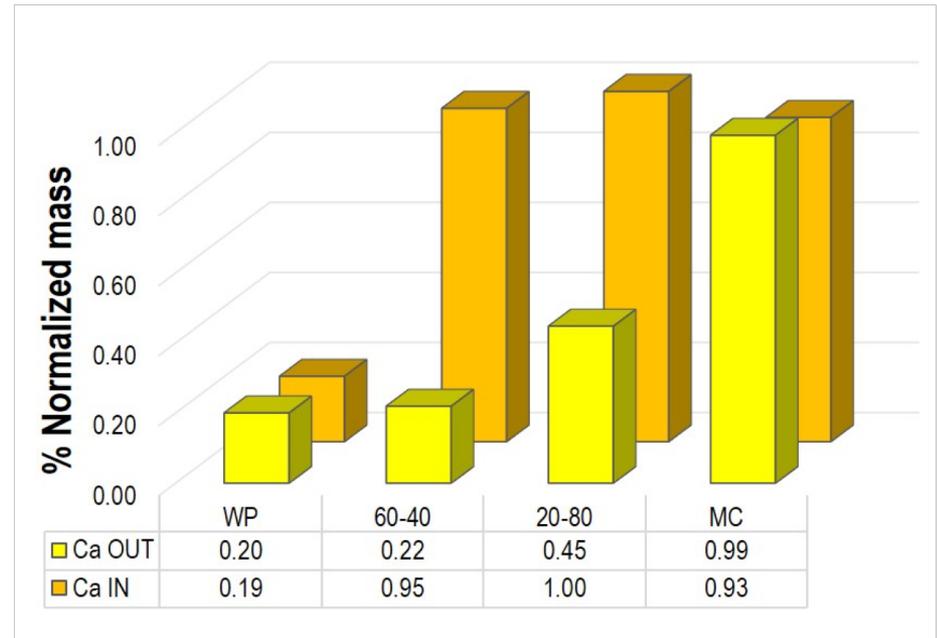
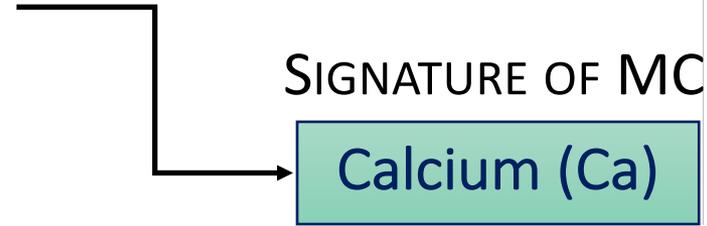
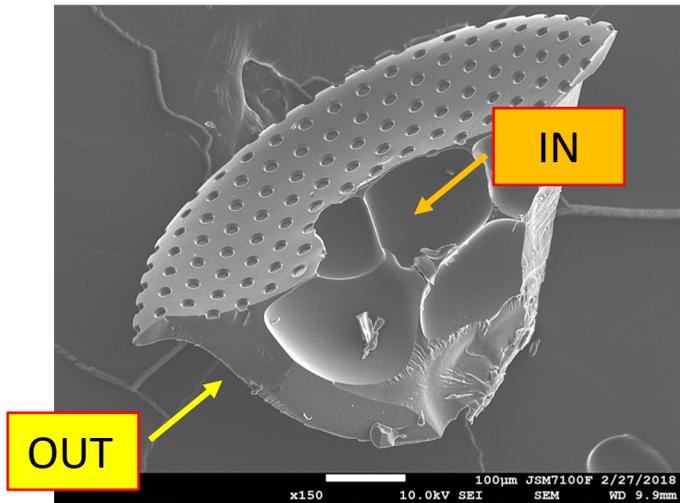
Flying monodisperse droplets Optical Microscopy



In this case of protein mixes, the major protein rules the transition and final shape of the droplet / particle

Is the skin composition representative of the bulk?

Elemental analysis by SEM (EDS)

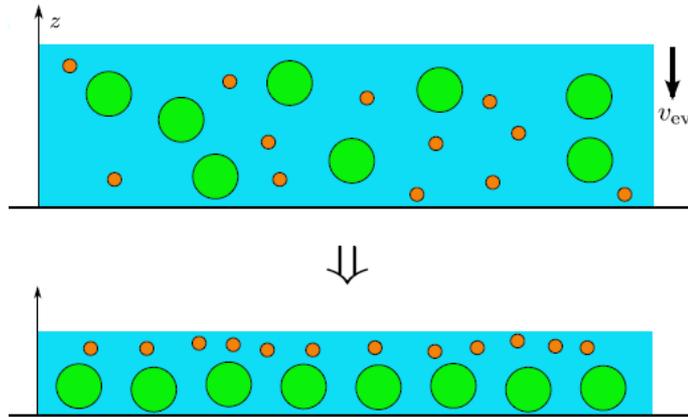


Over-representation of WP on the external part of the dry skin in WP/MC mixes: how to explain such behavior?

Colloids and Surfaces A 553 (2018) 20-27



Drying-induced colloid behavior



Small on top theory

FILM FORMATION IN BINARY COLLOIDAL MIXTURES

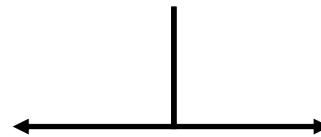
Due to osmotic pressure, smaller colloids accumulate on the external part of the skin/gelled layer passing through its interstitial pores

Zhou J. *et al.*, PRL 118, 108002 (2017).
Fortini A. *et al.*, PRL 116, 118301 (2016).

Characterization of the sol-gel transition in dairy mixes

Control of the nutritional properties of the powders (rehydration)

Industrial application



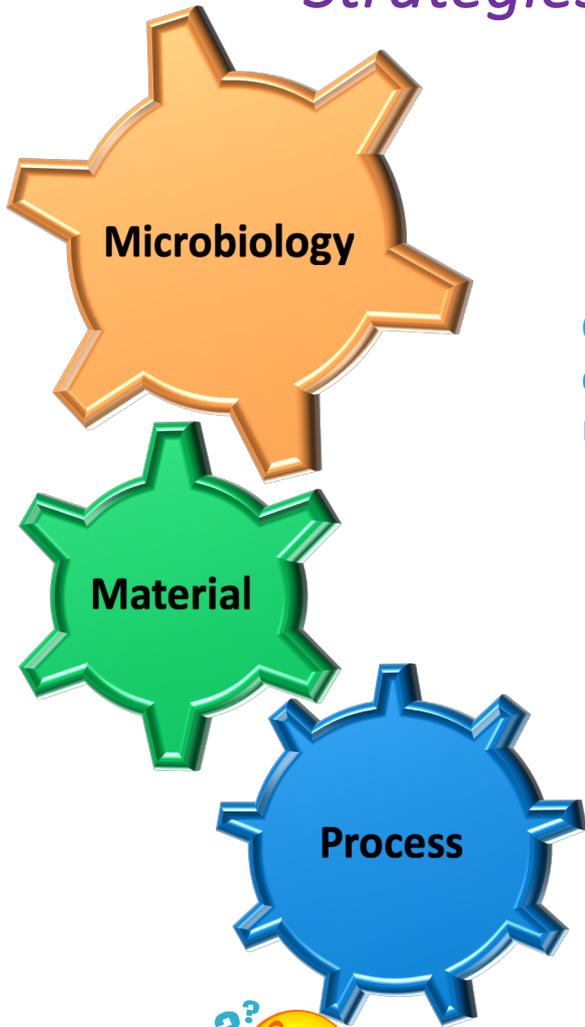
Understanding the drying mechanisms in colloidal polydisperse systems

Physics

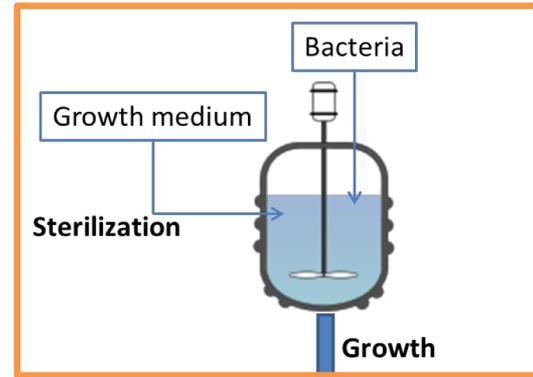
2.

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

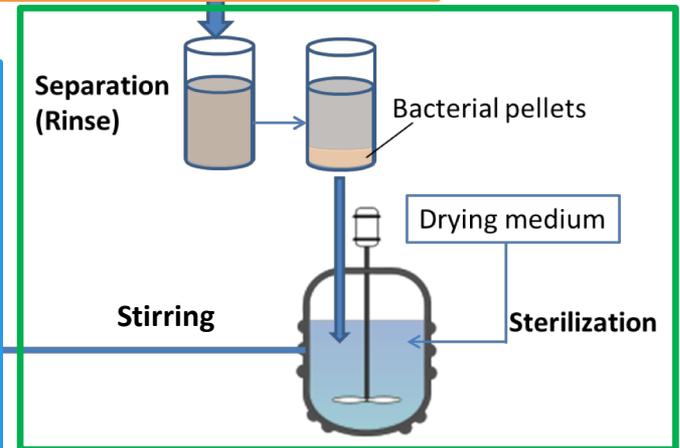
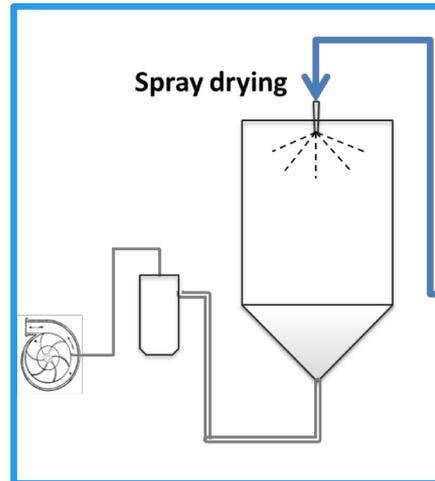
Strategies in probiotics drying research



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



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

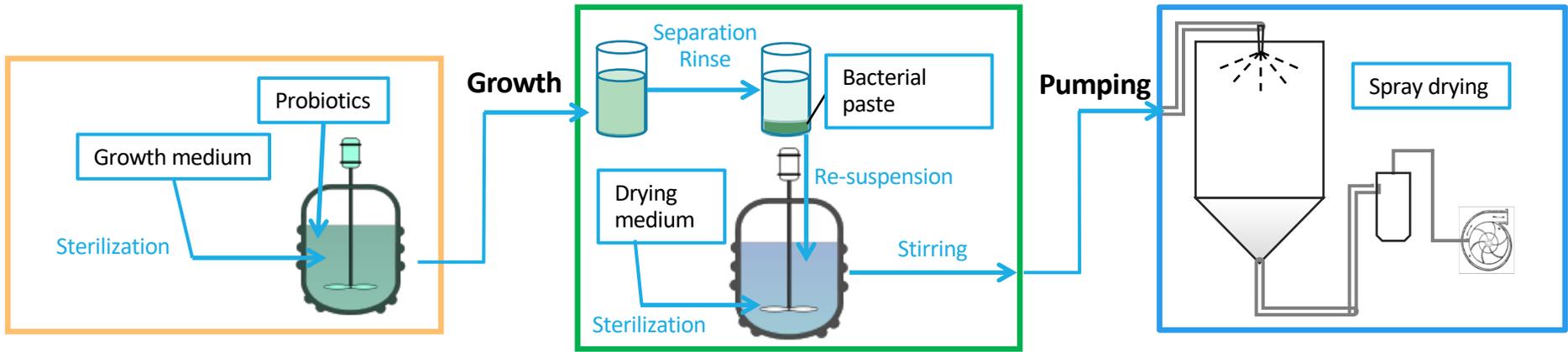


Protective food grade constituents: Carbohydrates, proteins, polymers, minerals

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
Carbohydrates
Proteins
Pre-concentration
Minerals
...

Multi-stage drying
Pre-concentration

Lower θ / Energy savings

Osmoregulation induce protection mechanisms before drying

L. casei
growth



30 SW

Optimal
content

Osmoregulation

Protein upregulation

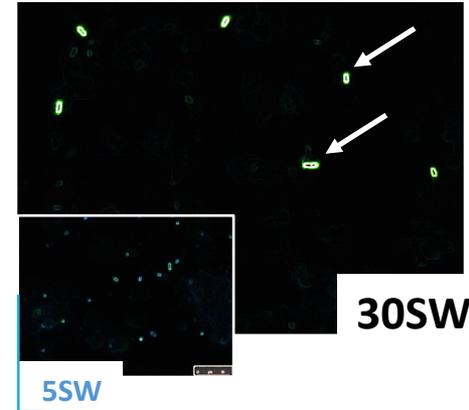
(Label-free proteomics):

- **Osmoregulation**
Glycine betaine transporter
- **Stress tolerance**
Chaperone, Cysteine synthase

+

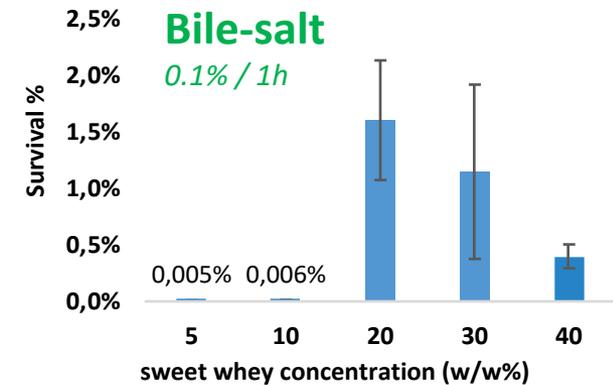
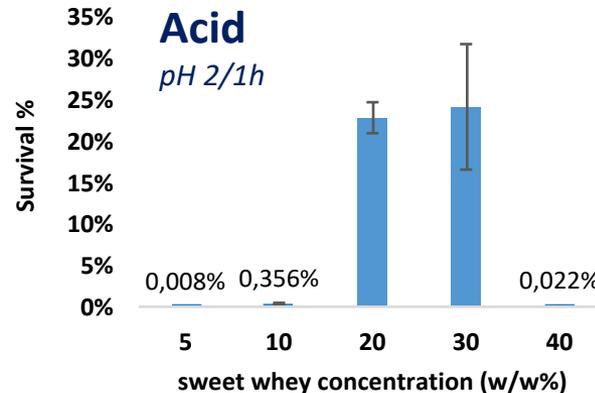
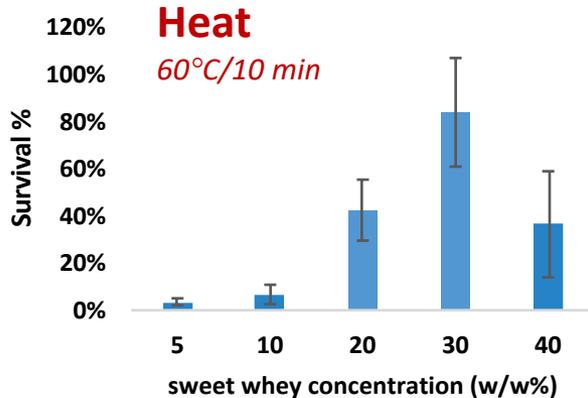
Accumulation

- **Polyphosphates**
- **Glycogen** (*energy for long term survival*)
- **Trehalose** (*involved in anhydrobiosis*)



Multi-stress resistant phenotype

App Env Microbiol 82
(2016) 4641 - 4651

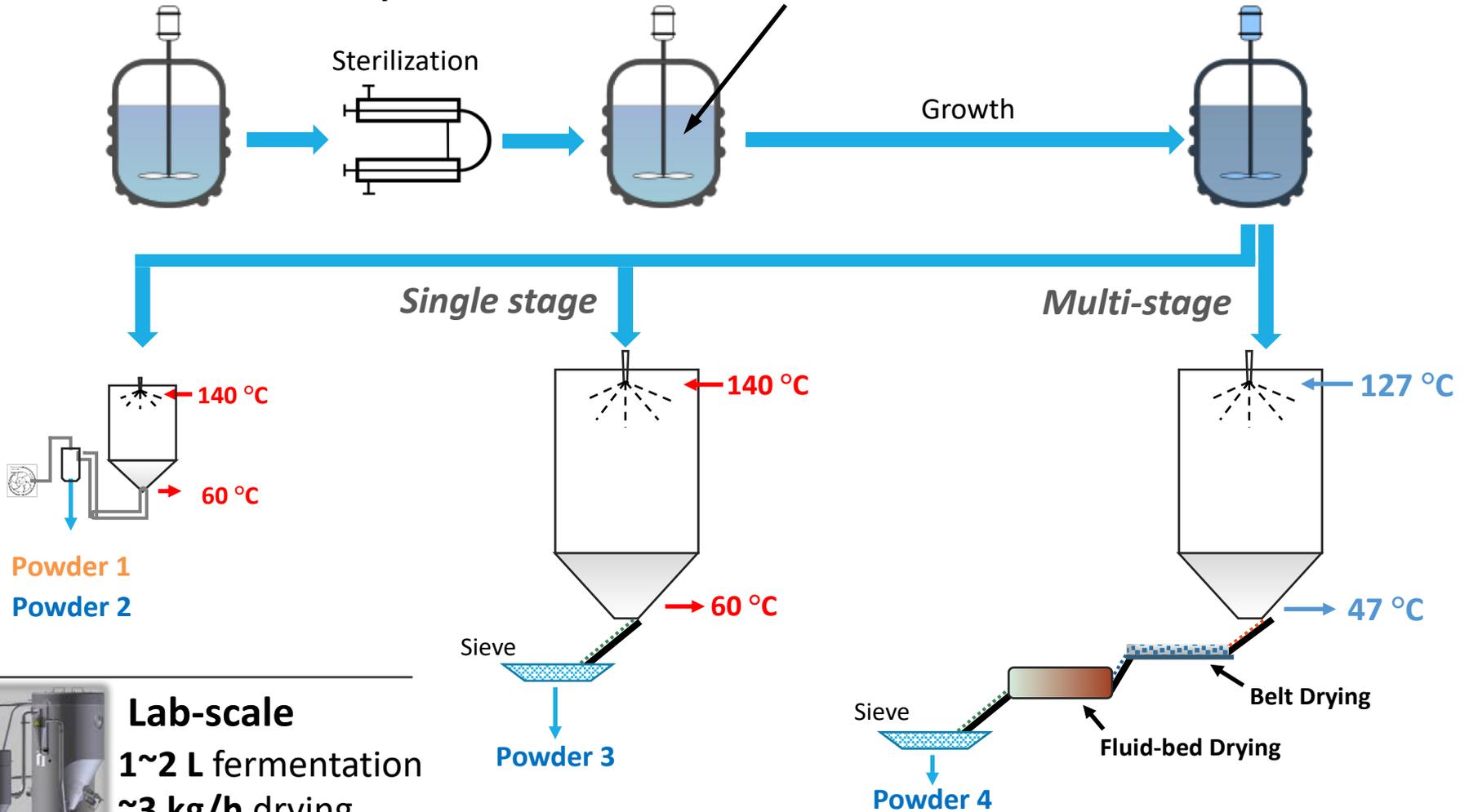


Drying bacteria at different scales

5% or 30% sweet whey

Inoculation of bacteria

Bacterial culture



Lab-scale

1~2 L fermentation
~3 kg/h drying

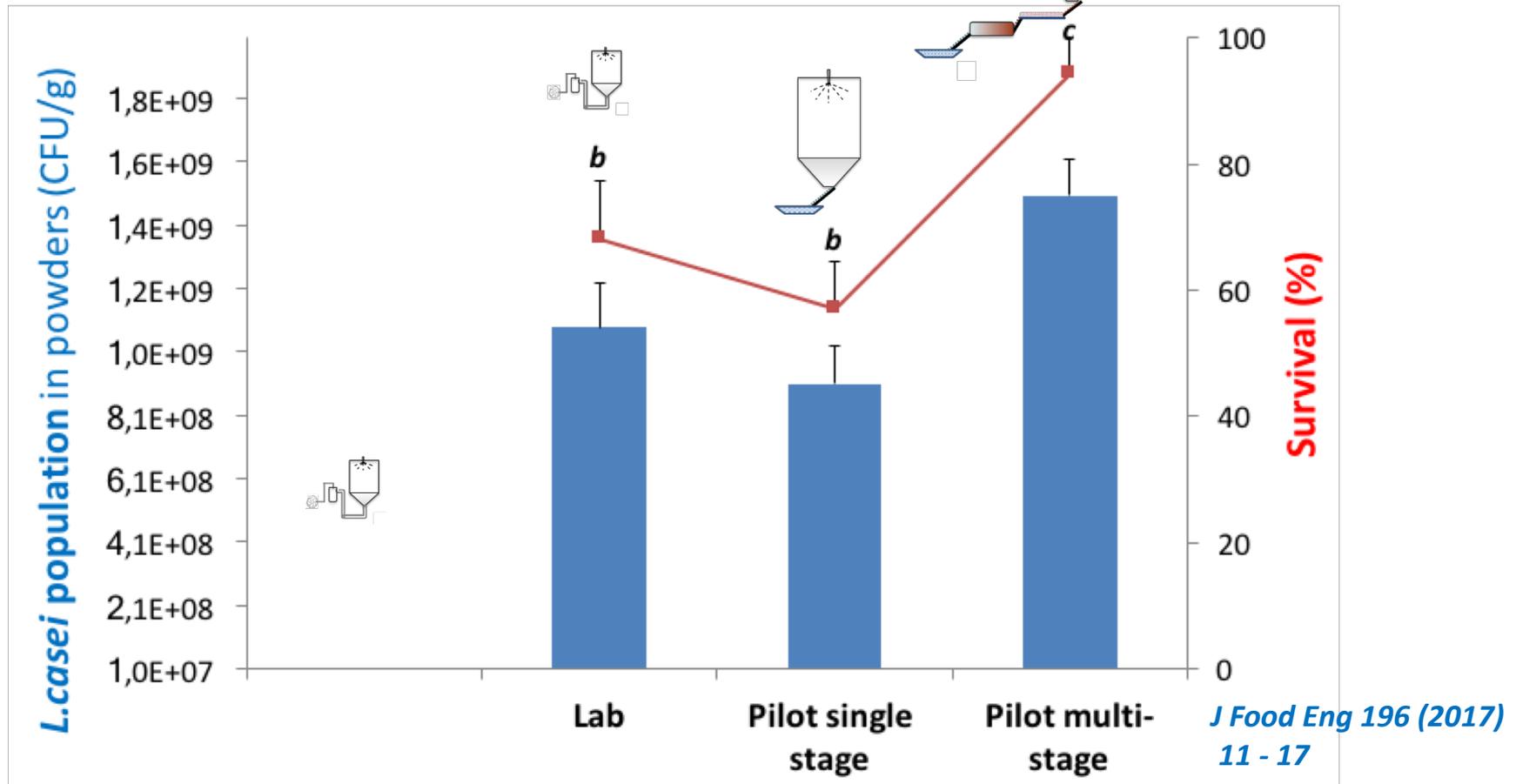


Pilot-scale BIONOV

500 L fermentation
~100 kg/h drying

J Food Eng 196 (2017) 11 - 17

Bacteria survival upon drying

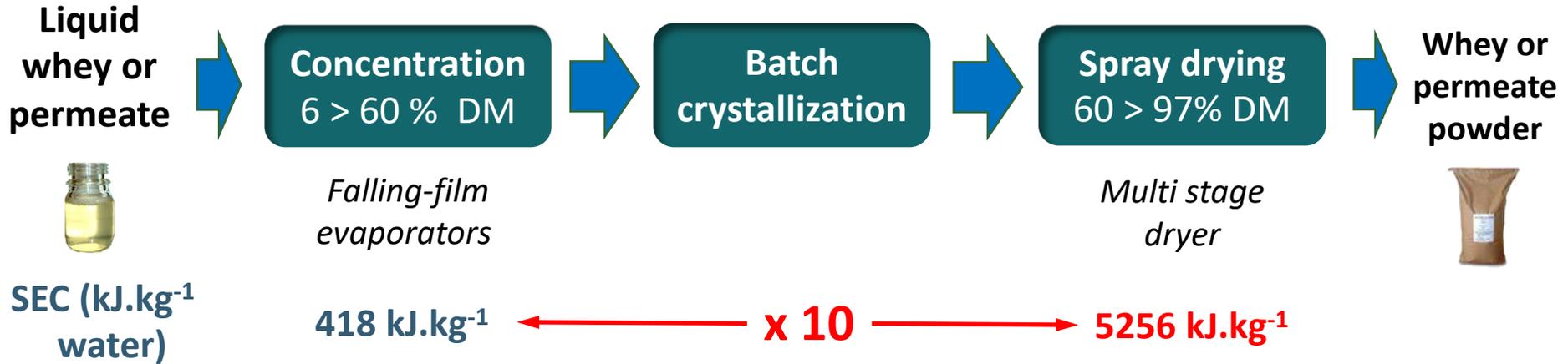


Acquired cross protection with multi stage scheme provides 100% survival
⇒ Patented process EP 15 306465.4 - 1357

3.

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

Current bottlenecks in whey/permeate powder production

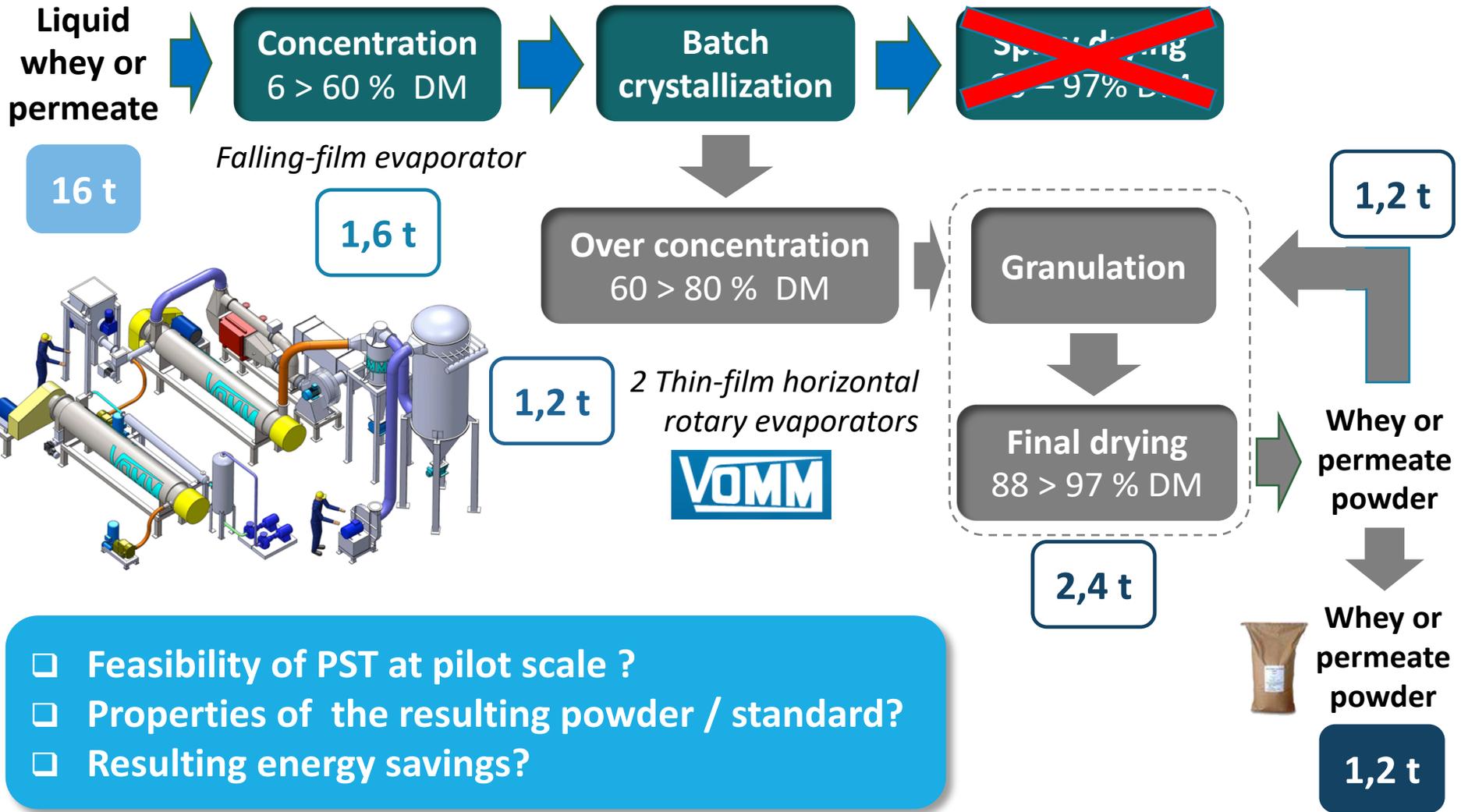


↗ concentrate DM, but limiting viscosity / pumping and spraying

55% of the overall energy for # 4% of the water removed

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

PST: a new process for whey/permeate powder production

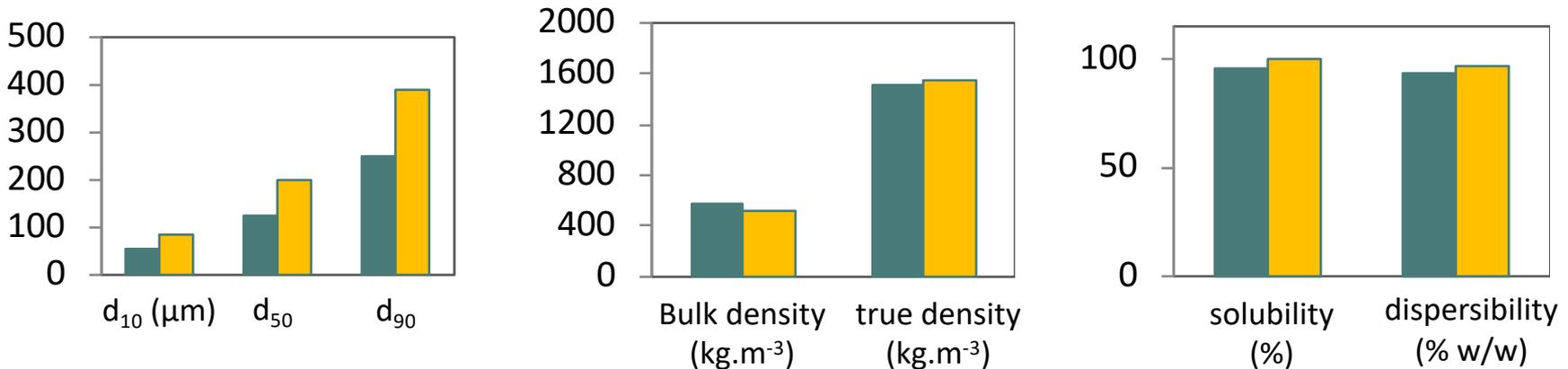


- Feasibility of PST at pilot scale ?
- Properties of the resulting powder / standard?
- Resulting energy savings?

Similar powder characteristics, lower energy requirements

- ❑ PST process was run successfully for **long duration experiments > 6 hours**

- ❑ **Non significantly different features of PST powder**  **compared to control** 



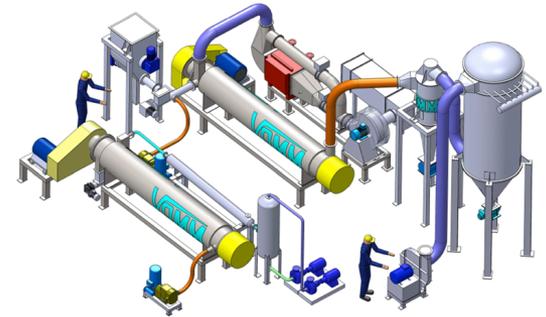
- ❑ **PST process significantly saves energy compared to the standard drying process**
 - ❑ Estimation of energy costs on the sole basis of the energy required for removal of water
 - ❑ **Drying step (60 to 97 % DM): 32% energy savings**
 - ❑ **Whole process (6 to 97 % DM): 11% energy savings**

Innov Food Sci Emerging Technol 41 (2017) 144 -149

PST process in short

VALIDATION

- Feasibility of PST process at pilot scale / long duration for the production of permeate powder
- Satisfactory properties of the resulting powder



REDUCTION

- Energy savings estimation range from 10 to 30%
- Building savings estimated at 40%
- Water, CIP solutions and waste volumes should be cut as well

INNOVATION

- Potential new products ...
- Produced in a sustainable way...
- Using breakthrough innovation

Patent EP 15752957.9 - 1358 (2015)

Conclusion and perspectives

Extensive work on IMF formulation is needed

- Determines nutritional properties
- **Conditions particle intrinsic features, then powder properties**
- **Enhances probiotics survival** during drying and in the dry state

Research strategy to overcome industry challenges

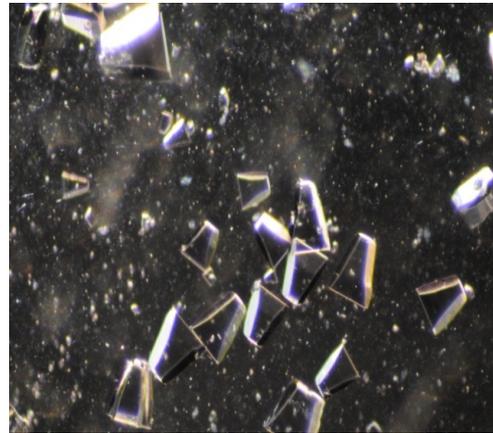
- Needs to **address growing market bottlenecks / societal issues**
- **Identifying the mechanisms at small scale, scale up needed**
- **Multidisciplinary approach** is mandatory: physics / biology / *medical*

Next step in IMF research / development

- Understand the mechanisms governing the skin formation in colloid mixes
- Better control the end use properties while **considering real complex formula in single drop experiments**



MERCI



***THANK YOU FOR
YOUR ATTENTION***