# Energy-efficient process for the manufacture of dairy powders using superconcentration and granulation

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# Energy-efficient process for the manufacture of dairy powders using superconcentration and granulation

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# Energy consumption of dairy powder production

**Spray-drying** → gold standard to manufacture of dairy powders but **energy-intensive operation**

CONCENTRATION

- membrane filtration (reverse osmosis/nanofiltration)
- falling-film evaporation
- membrane filtration → falling-film evaporation

DEHYDRATION

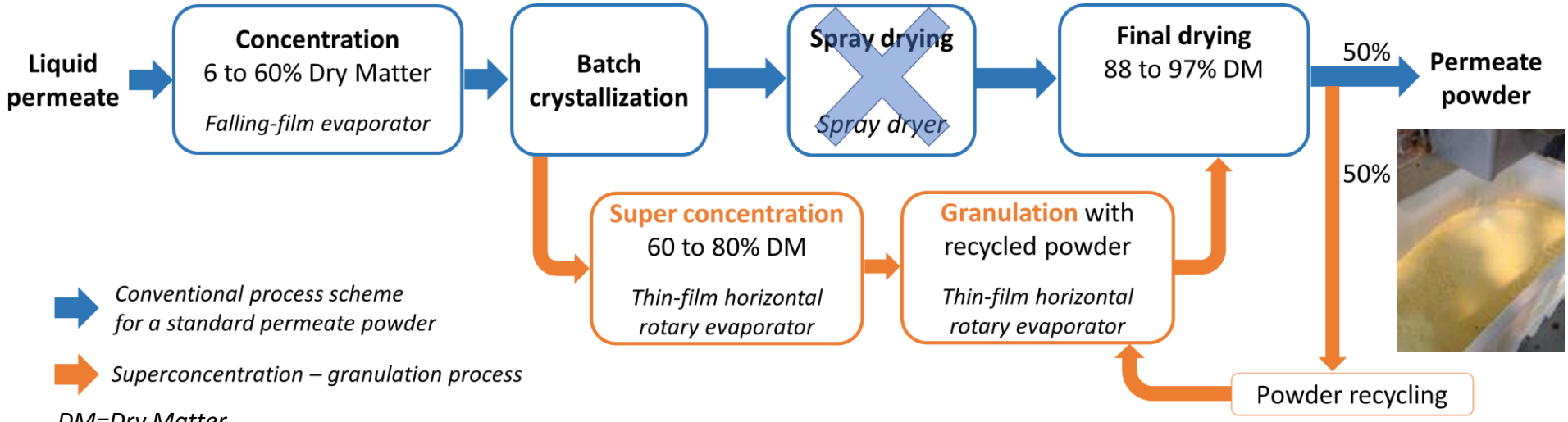
Spray drying

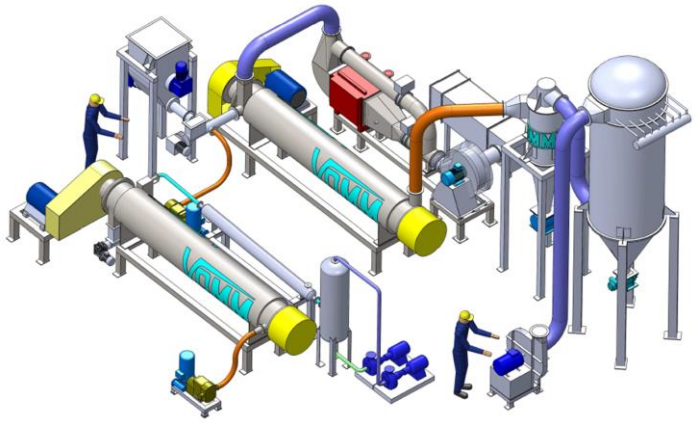
| | Concentration | dehydration |
|---|---|---|
| | FF evaporation | Spray drying |
| % of primary energy demand of the powder production process | 45 | **51** |
| % of removed water | Up to 90 % | **Less than 10 %** |
| Specific energy consumption ($kJ.kg^{-1}$ of removed water) | 70-500 | **3500-4500** |

*(Ramirez, 2006)*

**Alternative technologies to replace spray-drying ?**

# Application of a superconcentration-granulation process for the production of permeate powder

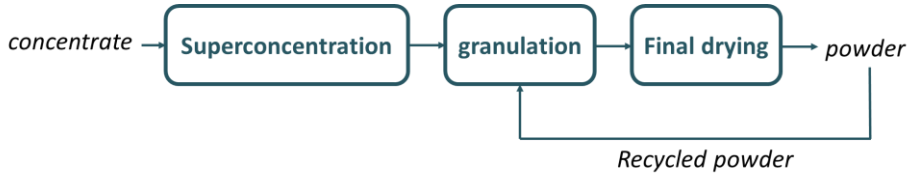


- Shear-thinning behaviour of permeate concentrates
- Application of a vigorous mechanical agitation in the rotary evaporator

→ **The rise in viscosity during concentration is counteracted by the high shear**

# Objectives and strategy




- ✓ Proof of concept demonstrated at pilot scale for the production of permeate powder and satisfactory properties of the resulting powders
- ✓ Energy savings estimated between 10 to 30% (on the sole basis of the energy required for water removal) // Building savings estimated at 40% *(Tanguy et al., 2017)*

❑ 2 limiting factors:

**the extent of superconcentration**

**The *minimum recirculation rate** for effective granulation**

*Productivity*
*Energy savings*

*DM decreases from 80 to 75% DM* ⇒ *recirculation rate increases 2×*

**Investigate the disruptive spray-drying free process for the manufacture of dairy powders**

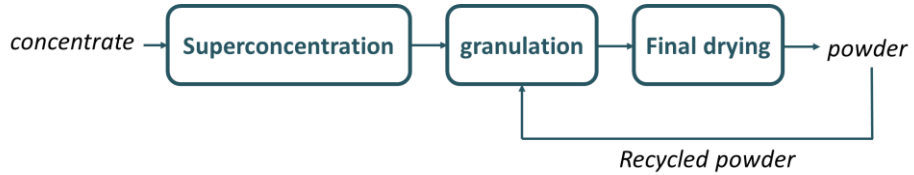
- **Evolution of physical properties of dairy products ? Limits of superconcentration ?**
- **Influence of composition of dairy streams ?**

→ Development of a lab-scale model to mimic the novel process // use of different techniques and analytical tools for the characterisation of products and process (application to permeate from skim milk microfiltration);

→ Application to dairy streams of different compositions

* Ratio of superconcentrated paste over recycled powder for which fragmentation of paste into granules occurs

# Lab-scale protocol

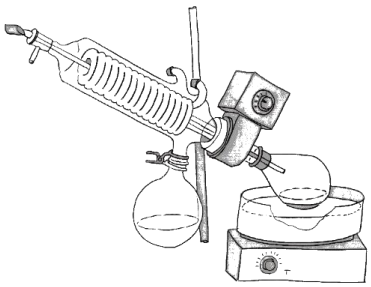


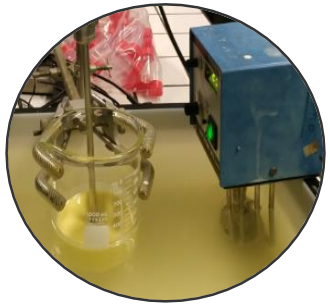

*Viscous concentrate*

*Highly cohesive paste*

*Non-sticky granules*

**Concentration** 30 to 60 % DM → **Lactose crystallization** → **Super-concentration 60 to 80% DM** → **granulation** → **Final drying 88 to 97 %**



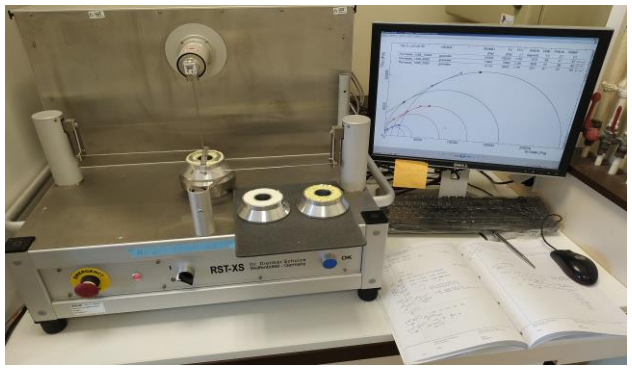


*High shear temperature-controlled mixer*

# Characterisation of products and process

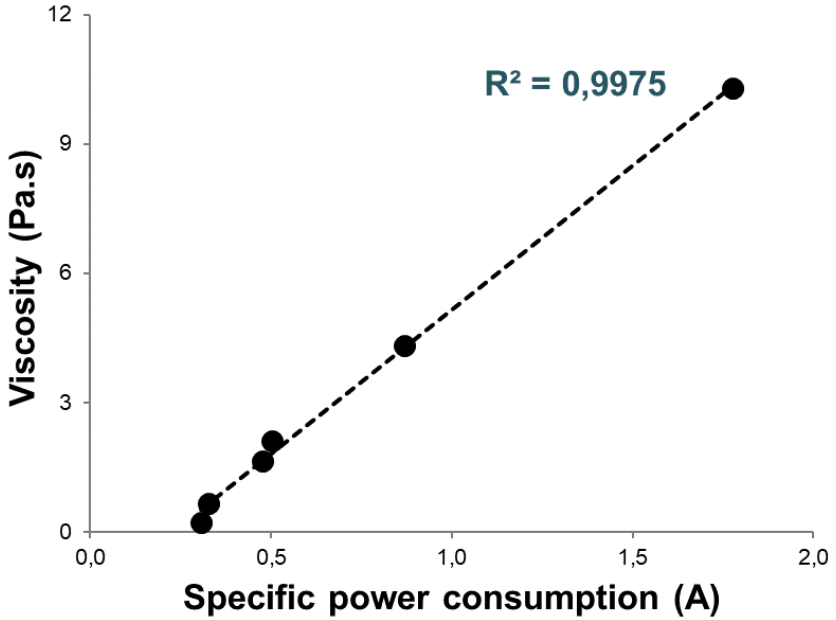
**Rheometer**
flow behaviour of concentrates

**Probe-track test**
cohesion of high cohesive concentrates




**Shear-cell test (RST)**
cohesiveness and flowability of superconcentrated pastes and granules


**Ampere power meter**
energy consumption of mixer



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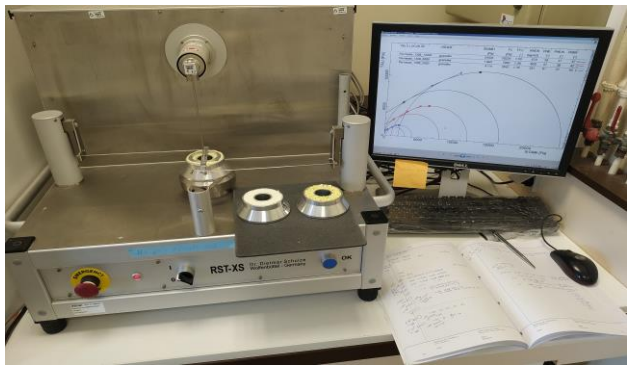


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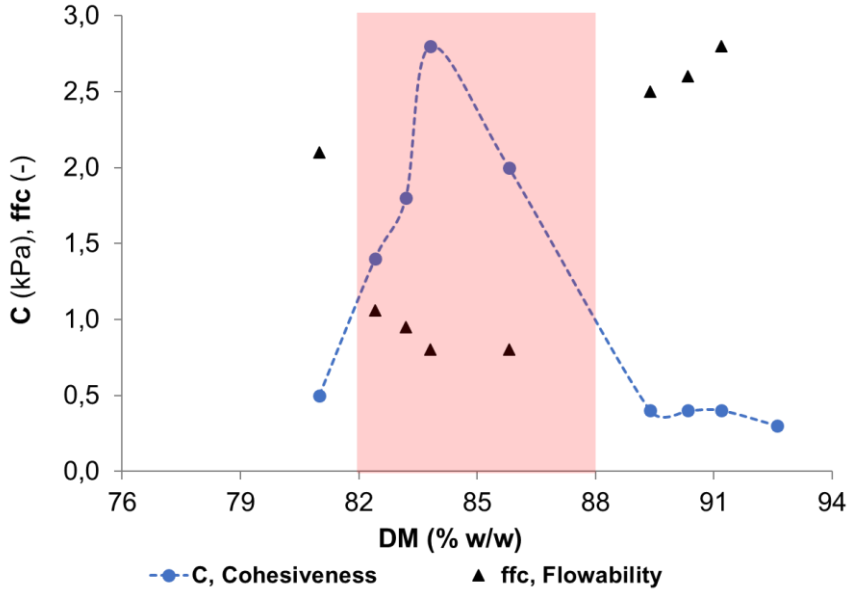
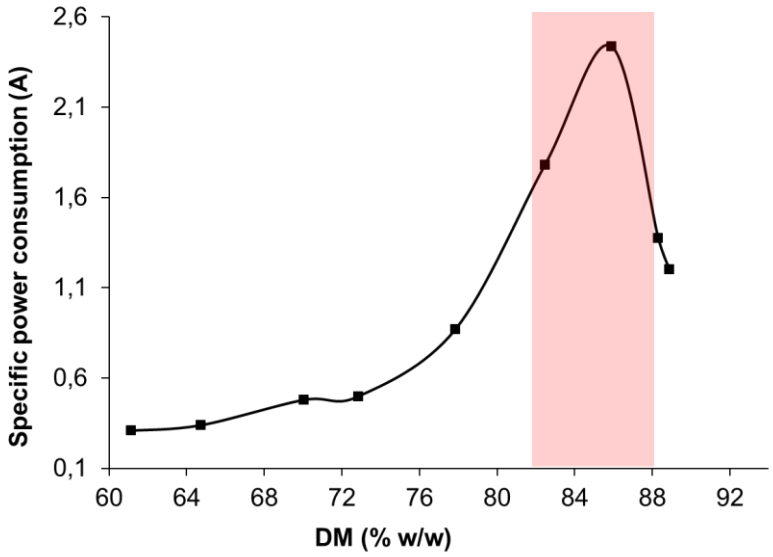
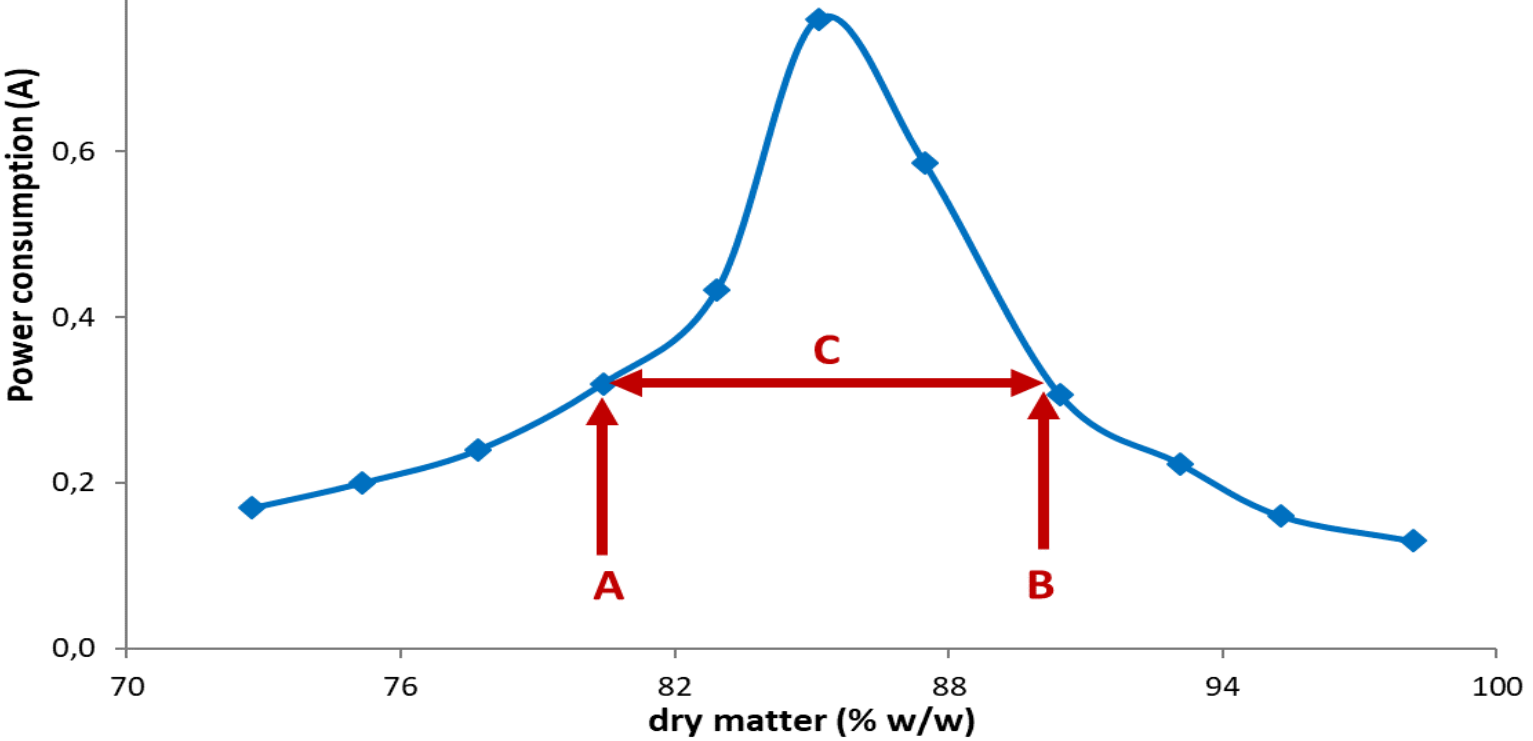



Highly cohesive (sticky) phase

# A reliable protocol to identify crucial parameters of the superconcentration-granulation process

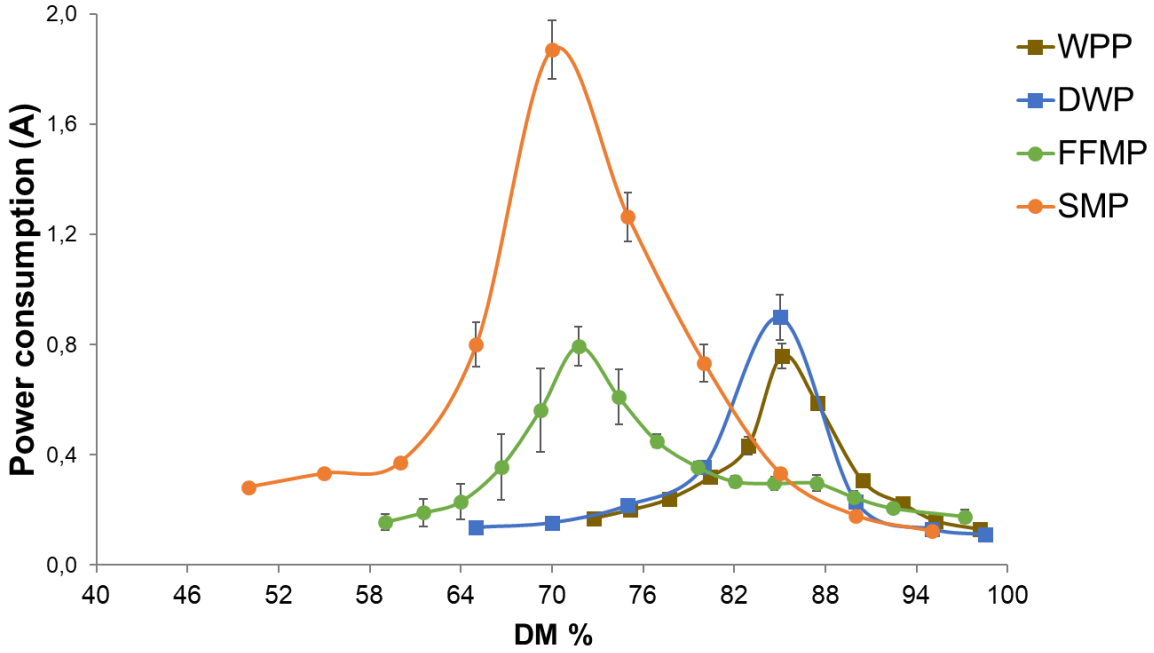
*Viscous concentrate* ← *Highly Cohesive (sticky) mass* → *Non-sticky granules*




A = onset of a highly (sticky) cohesive phase → ***maximum surconcentration***
B = end of cohesive phase → ***minimum recirculation rate*** for granulation
C = highly cohesive phase

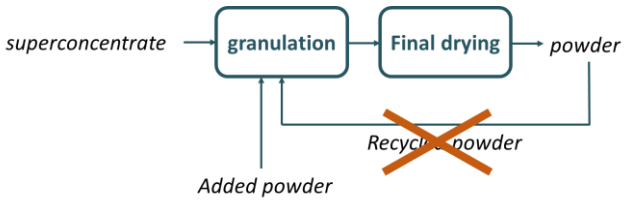
# Influence of composition of dairy streams on the superconcentration process

| | Partial specifications of the powders used as raw materials for the study | | | |
|---|---|---|---|---|
| | Whey permeate (WP) | Demineralized whey (DW) | Fat-filled milk (FFM) | Skim milk (SM) |
| Protein content (% w/w) | 2.5 | 12.0 | 24.0 | 34.0 |
| Lactose content (% w/w) | **85.5** | **83.5** | 38.0 | 54.8 |




- **Great influence of composition** on product-process interactions
- **Higher lactose dairy streams** can be favourably produced using superconcentration-granulation process

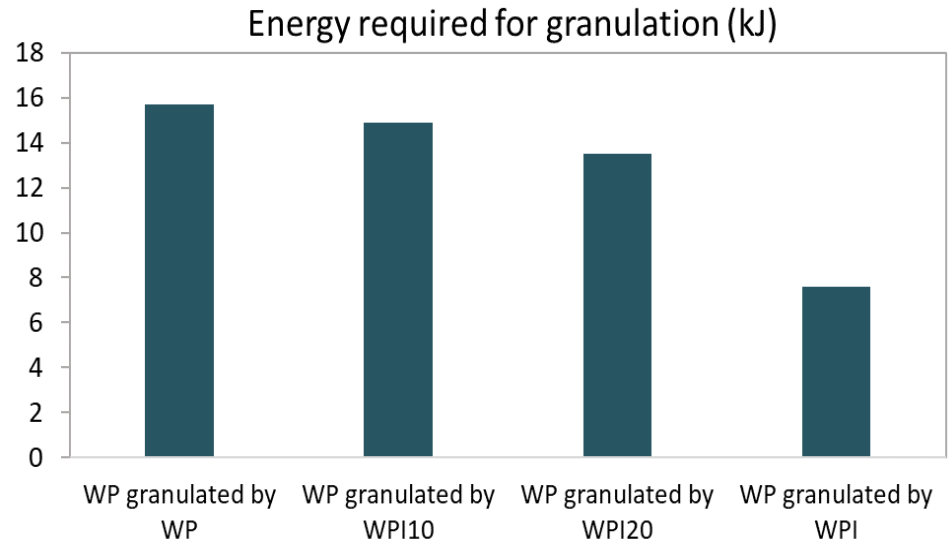
# Influence of the composition of the back-mix fraction on granulation

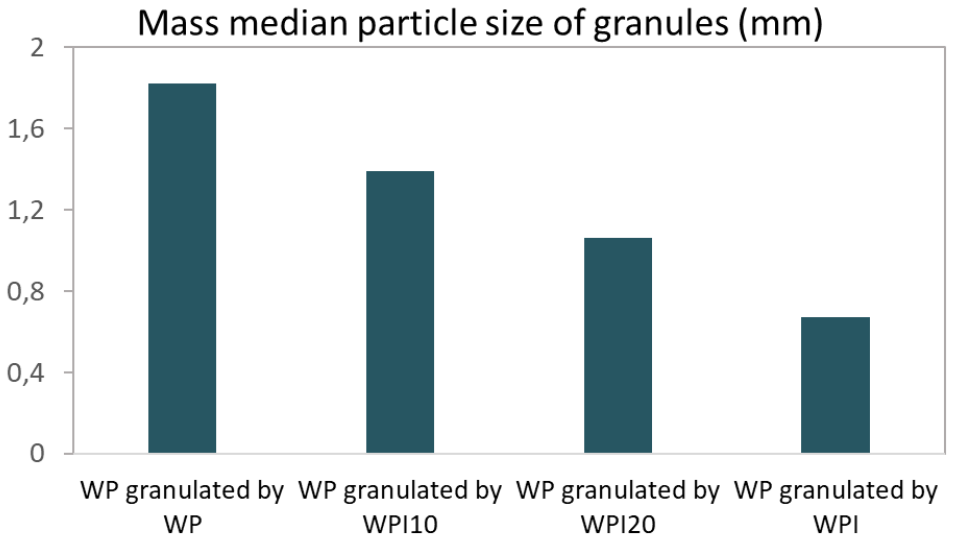


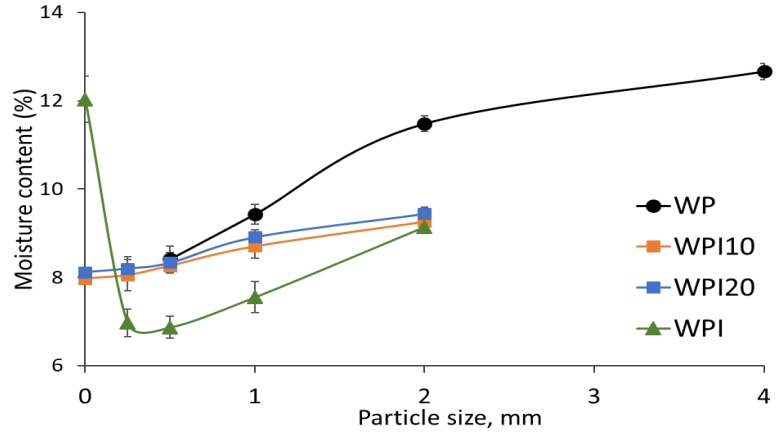

**Granulation of superconcentrated whey permeate paste** at 82.2 % w/w DM by:

- Whey permeate powder → **WP**
- blend of WP and WPI powders at 90:10 proportion → **WPI10**
- blend of WP and WPI powders at 80:20 proportion → **WPI20**
- Whey Protein Isolate powder → **WPI**

Constant back-mix fraction equal to 1:1 (superconcentrate:powder)




- **Complete or partial replacement of WP powder by WPI** resulted in **improved granulation performances** (smaller particules and lower energy consumption)

Related to higher water holding capacity of WPI compared to WP

# Conclusions & perspectives

**superconcentration**

- **Onset of a highly sticky cohesive phase limits** this step
- **Strong influence of lactose:protein ratio of dairy streams** on superconcentration performances → high lactose dairy streams are favourably produced

**granulation**

- **Recirculation rates (superconcentrate:powder)** is a key factor for granulation
- **Addition of protein powders improved granulation** performances

**A reliable lab-scale protocol to evaluate superconcentration-granulation approach for dairy and food powder manufacture**

- TRANSFER and VALIDATE THE LEARNINGS at a pilot scale (~100 $kg.h^{-1}$) → especially functionalities of granulated powders and energy savings potentials
- Manipulate dry powder addition rate by INTRODUCING NEW INGREDIENTS (WATER BINDING INGREDIENTS) INTO SUPERCONCENTRATED DAIRY PASTE to produce value added formulated products

**1 REVIEW:**

Patil, M. H., Tanguy, G., Floch-Fouéré, C. L., Jeantet, R., & Murphy, E. G. (2021). Energy usage in the manufacture of dairy powders : Advances in conventional processing and disruptive technologies. *Drying Technology*, *39*(11), 1595-1613.

**3 RESEARCH PAPERS:**

Patil, M. H., Murphy, E. G., Tanguy, G., Le Floch-Fouéré, C., & Jeantet, R. (2021). Characterization of the superconcentration and granulation steps of a disruptive spray-drying free process for the manufacture of dairy powders. *Journal of Food Engineering*, 110865.

Patil, M. H., Tanguy, G., Le Floch-Fouéré, C., Jeantet, R., & Murphy, E. G. (2021). Determination of limiting factors in a novel superconcentration-granulation based dairy powder manufacturing process. *Innovative Food Science & Emerging Technologies*, *74*, 102798.

Patil, M. H., O'Donoghue, L.T., Chutani, D., Tanguy, G., Le Floch-Fouéré, C., Jeantet, R., & Murphy, E. G. Granulation behaviour of high lactose dairy superconcentrates, *under review*

*Thank you for your attention !*

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