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

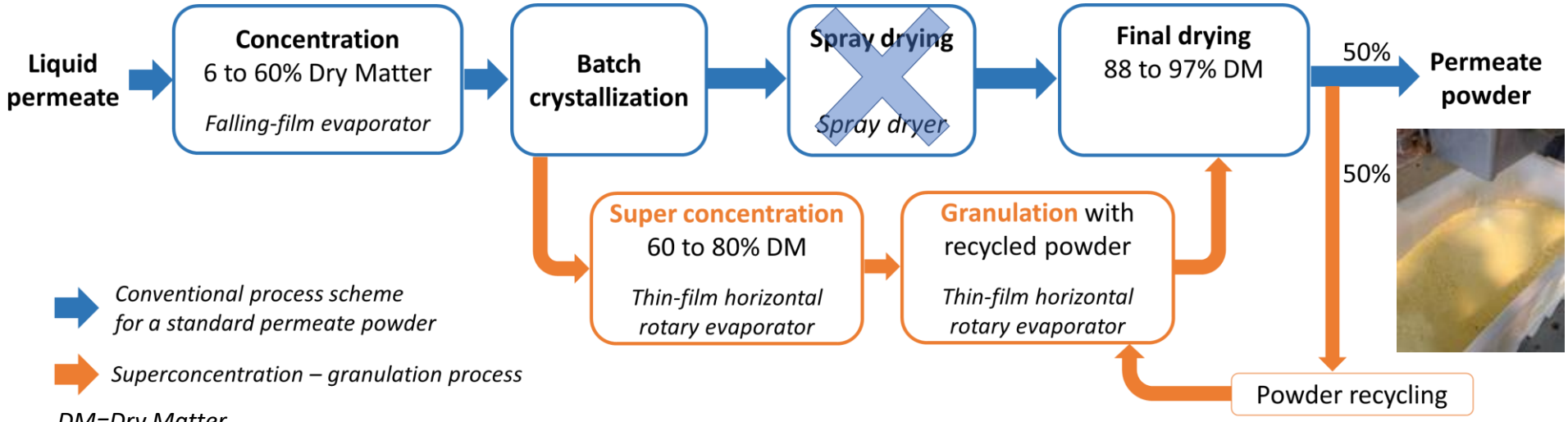
Spray drying

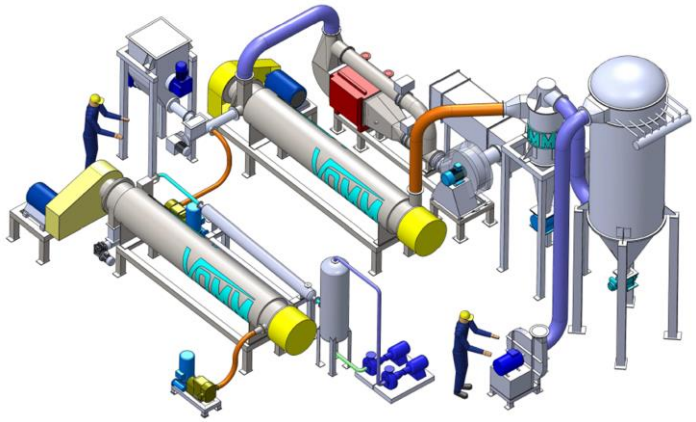
	Concentration	dehydration
	FF evaporation	Spray drying
% of primary energy demand of the powder production process	45	**51**
% of removed water	Up to 90 %	**Less than 10 %**
Specific energy consumption ($kJ.kg^{-1}$ of removed water)	70-500	**3500-4500**

(Ramirez, 2006)

Alternative technologies to replace spray-drying ?

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

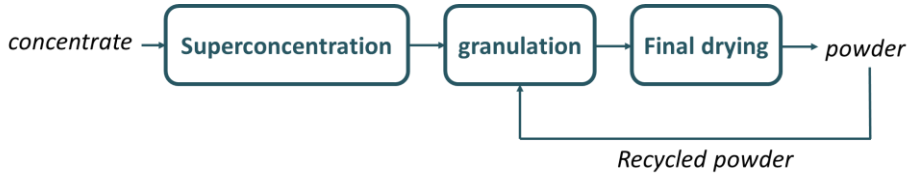




- Shear-thinning behaviour of permeate concentrates
- Application of a vigorous mechanical agitation in the rotary evaporator

→ **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

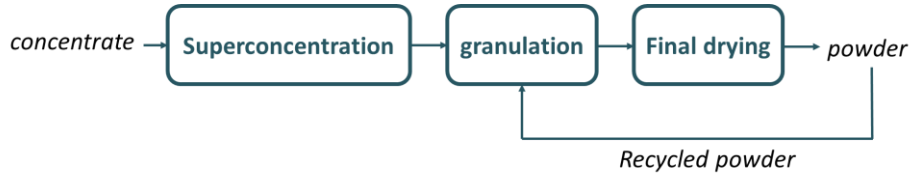
- **Evolution of physical properties of dairy products ? Limits of superconcentration ?**
- **Influence of composition of dairy streams ?**

→ 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

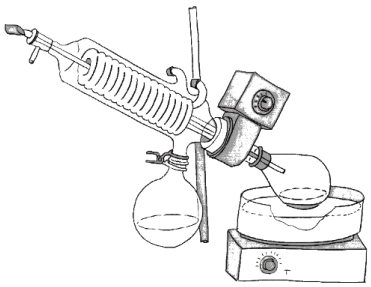


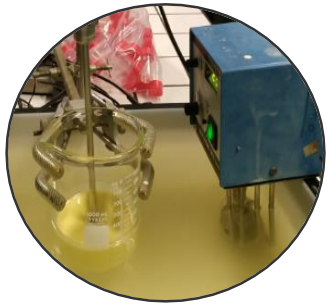
Viscous concentrate

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 %**



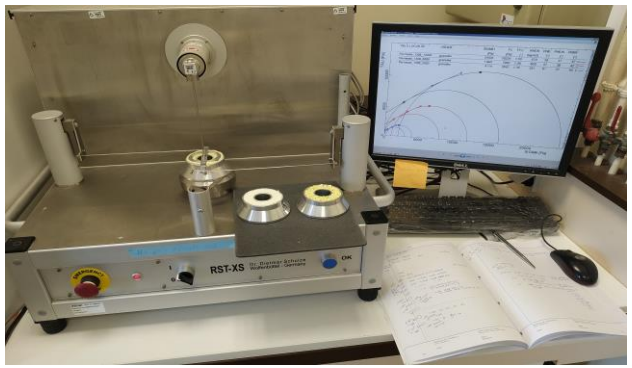


High shear temperature-controlled mixer

Characterisation of products and process

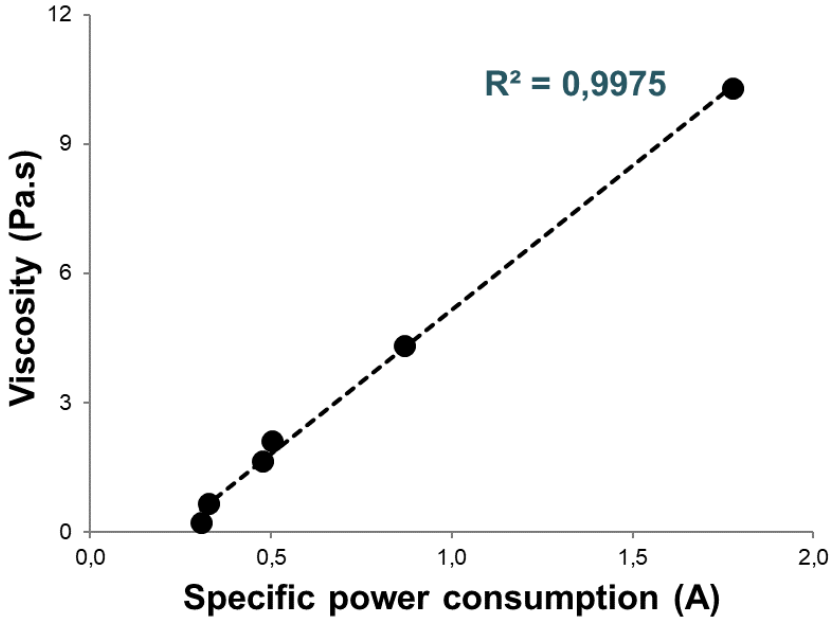
Rheometer
flow behaviour of concentrates

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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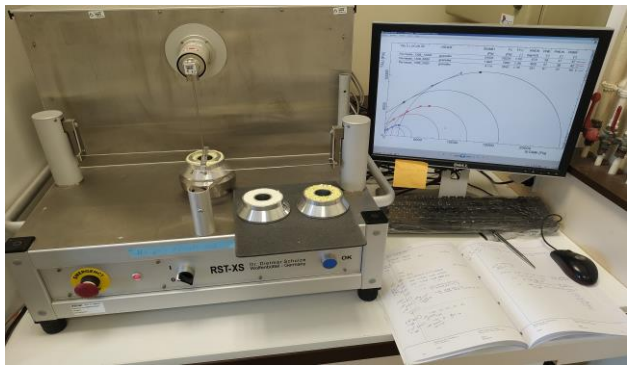

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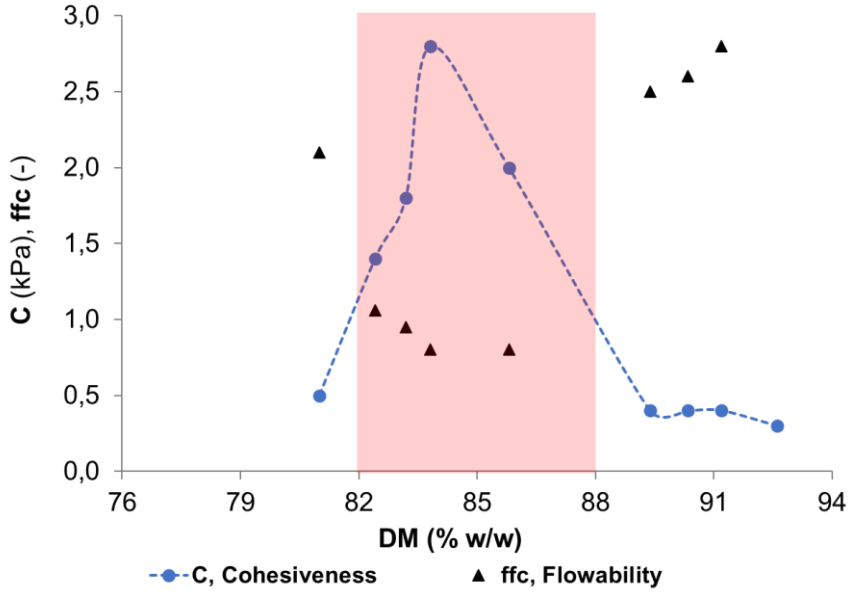
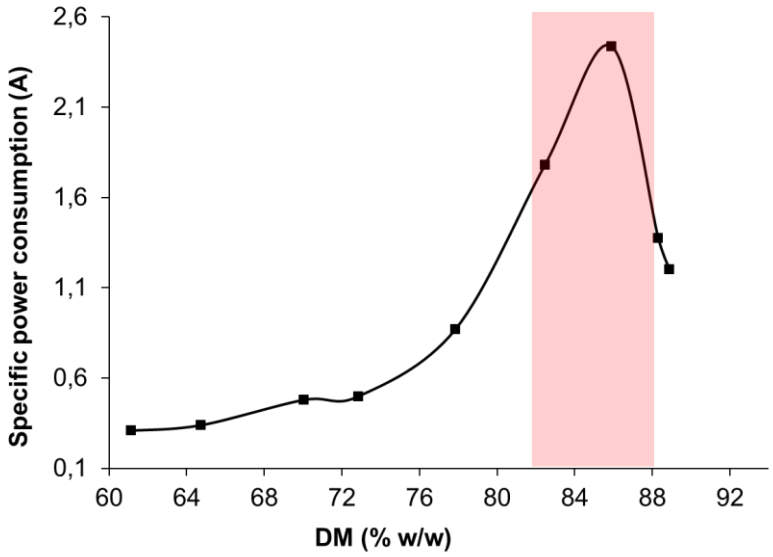
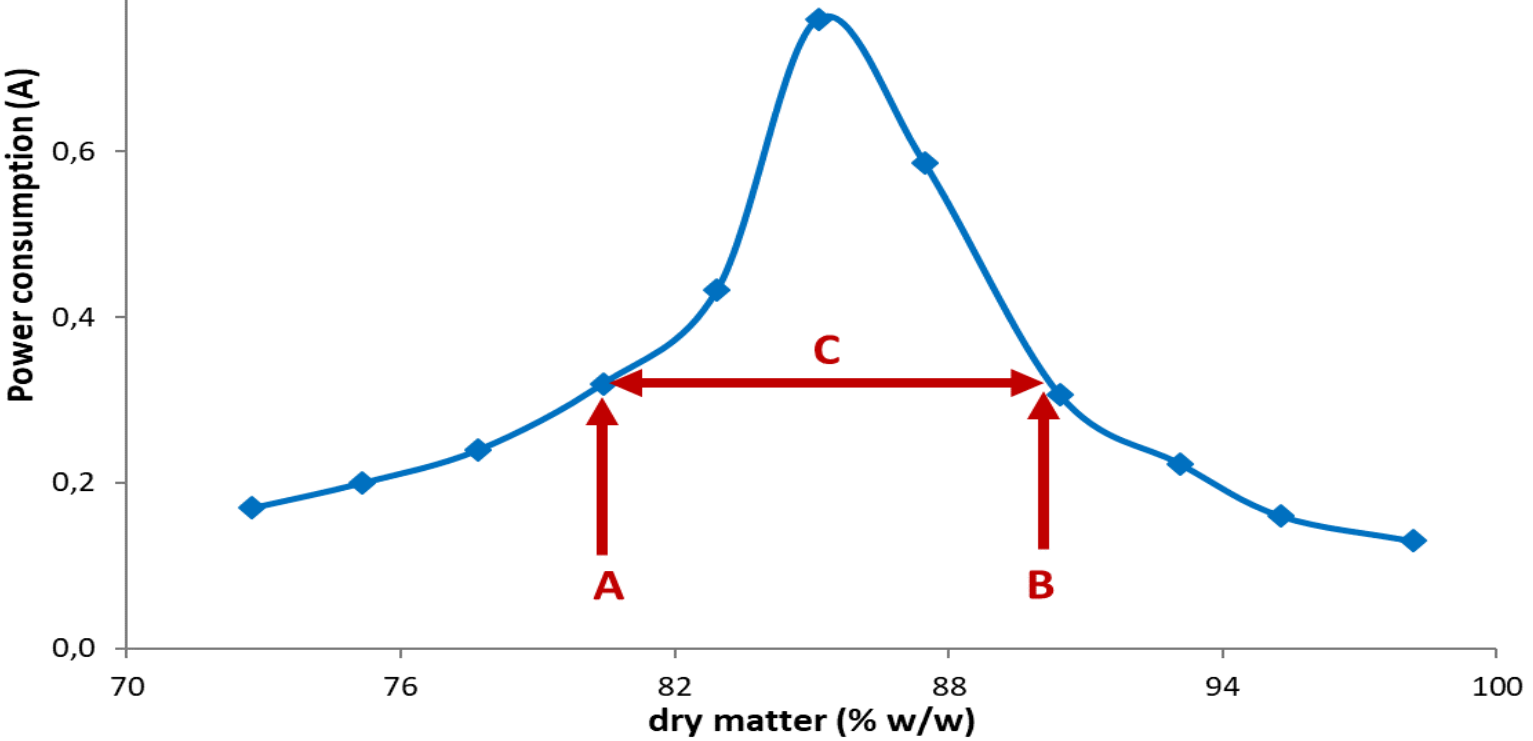




Highly cohesive (sticky) phase

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

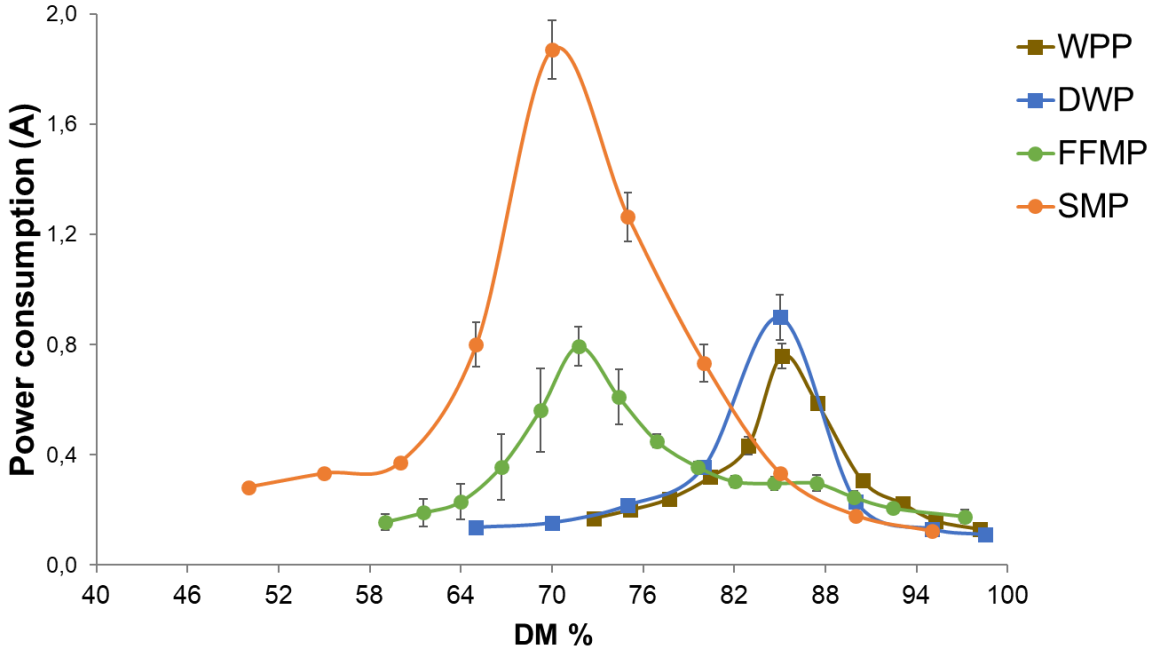
Viscous concentrate ← *Highly Cohesive (sticky) mass* → *Non-sticky granules*



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

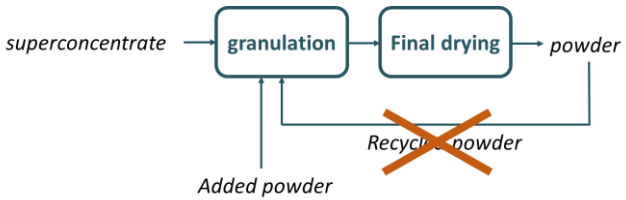
Influence of composition of dairy streams on the superconcentration process

	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

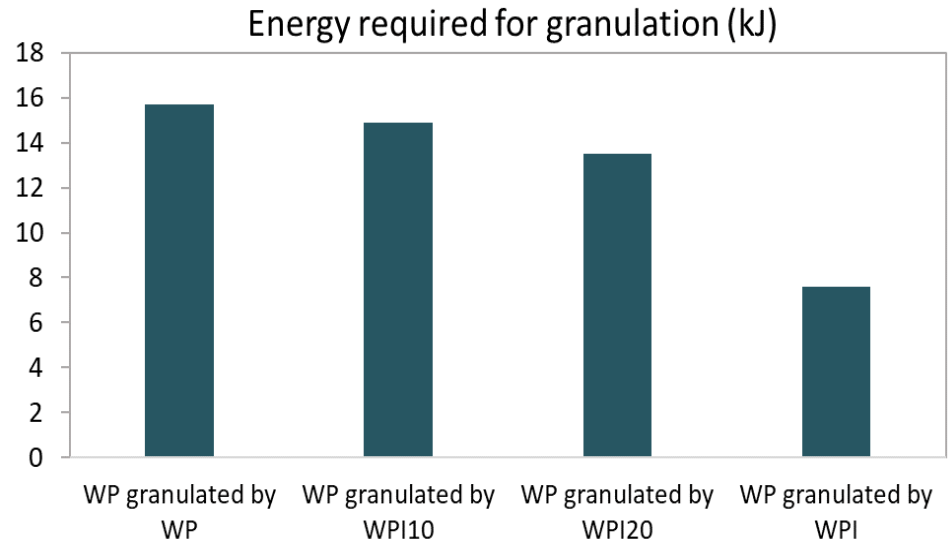
Influence of the composition of the back-mix fraction on granulation

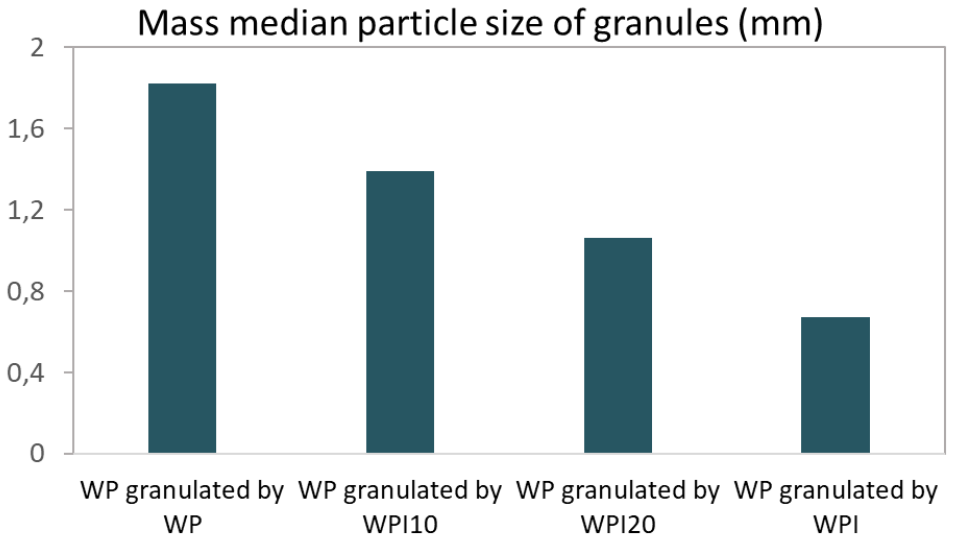


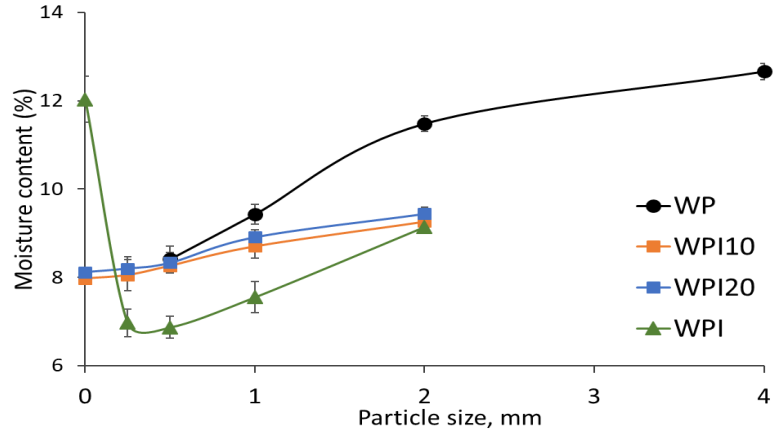
Granulation of superconcentrated whey permeate paste at 82.2 % w/w DM by:

- 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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