Unravelling the influence of composition and heat treatment on physico-chemical and functional properties of dairy protein powders

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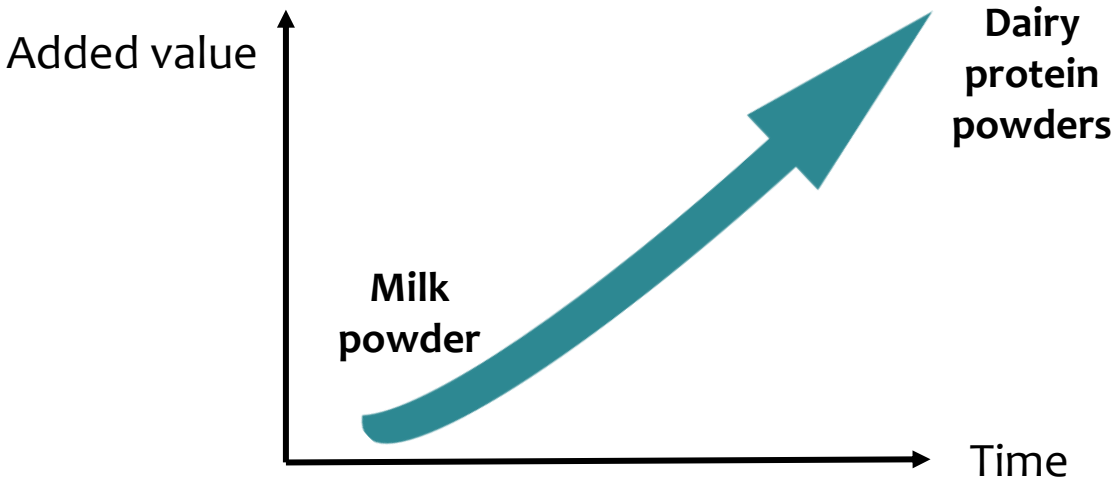
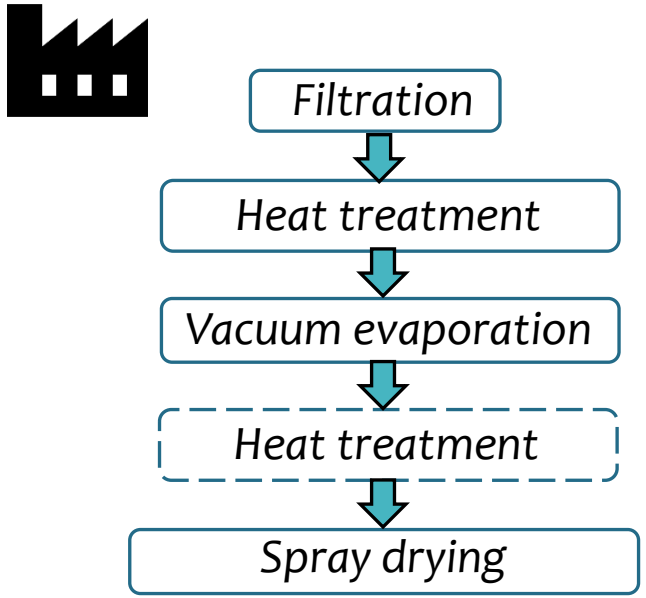
Milk -> dried dairy protein ingredients

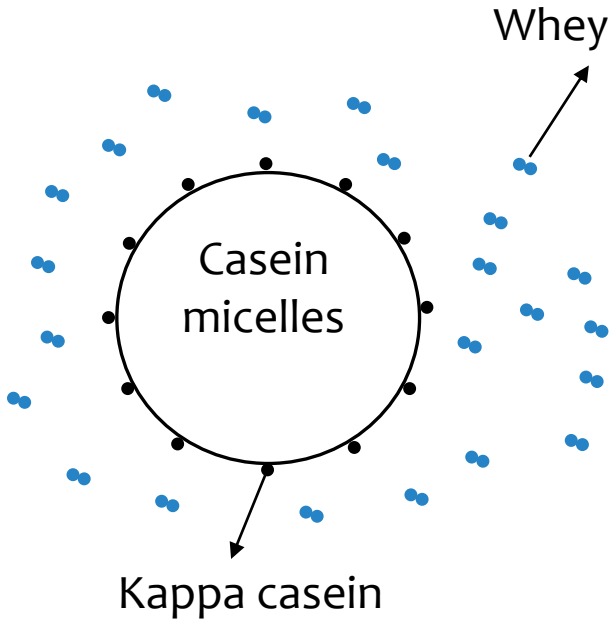
Dried forms:
Facilitated and reduced storage and transport
Extension of shelf life

Expanding market:
used in a wide variety of nutritional products as either base ingredients or complete nutritional products.



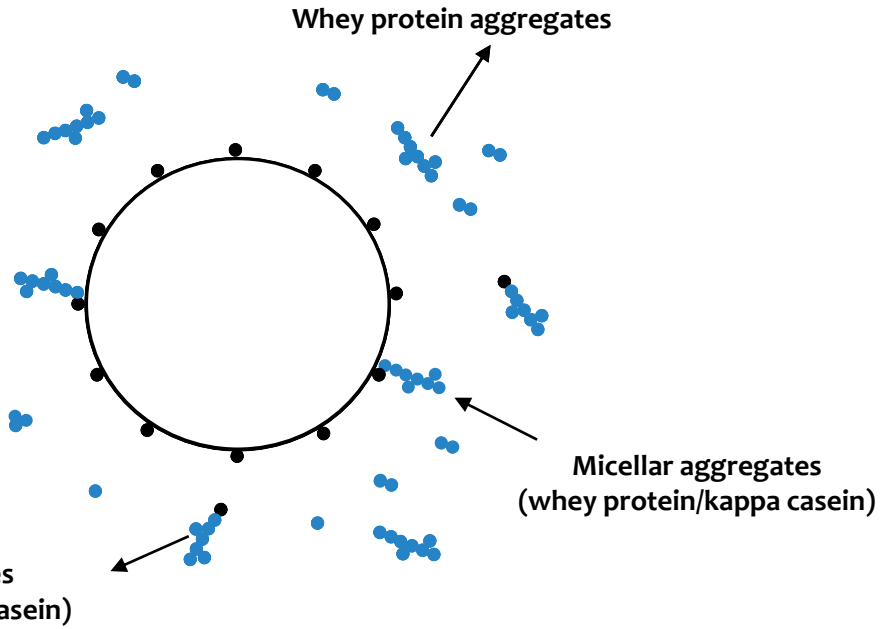


Dairy protein solutions during heat treatment



Process : Temperature, time

Physico-chimical conditions : pH, ionic force, casein:whey protein ratio, total protein content

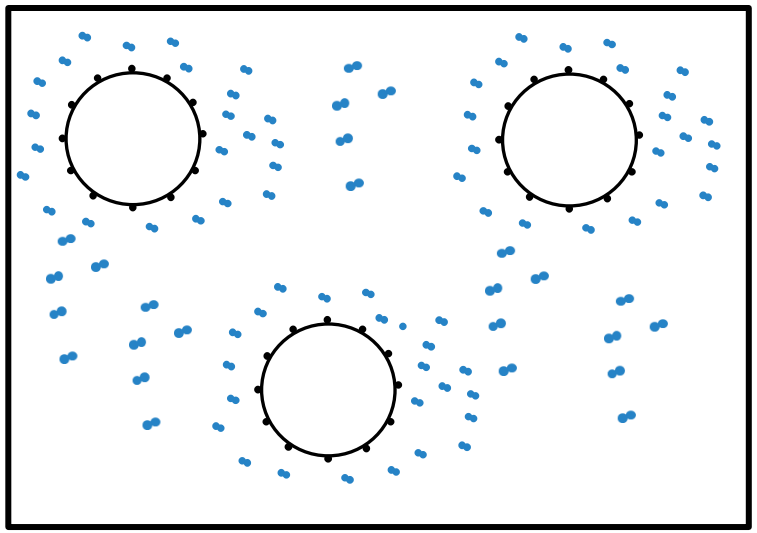


(Smits and Van Brouwershaven., 1980 ; Singh and Fox., 1985,1987 ; Anema and Klostermeyer., 1997 ; Oldfield et al., 2000 ; Anema and Li., 2003, Anema, 2009 ; O'Connell and Fox., 2003 ; Singh 2004 ; Donato and Guyomarc'h., 2009)

Heat treatment of proteins in the literature

Heat treatment of milk

[Proteins] = 33 g.kg^{-1}



Good understanding

(Smits and Van Brouwershaven., 1980 ; Singh and Fox., 1985,1987 ; Anema and Klostermeyer., 1997 ; Oldfield et al., 2000 ; Anema and Li., 2003, Anema, 2009 ; O'Connell and Fox., 2003 ; Singh 2004 ; Donato and Guyomarc'h., 2009)

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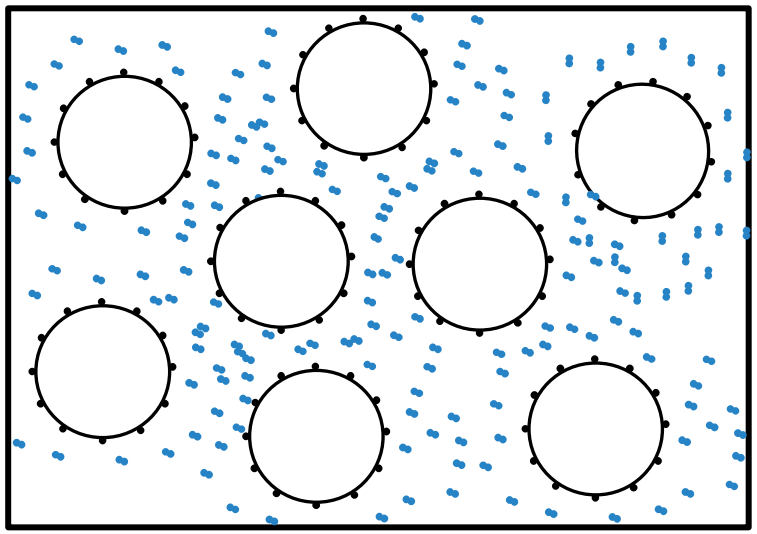
Heat treatment of concentrates of dairy proteins

[Proteins] = 100-300 g.kg^{-1}



Partial understanding

(Warncke et al., 2022; Ho et al., 2019; Mc Sweeney., 2022; Wolz and Kulozik., 2015)

Research question and objectives

What is the influence of formulation and process parameters on the properties of concentrated dairy protein powders ?

- What impact does the technological route have on the level of protein denaturation/aggregation?
- How are the properties of powders linked to their formulation and level of protein denaturation/aggregation?
- How does the powder evolve during storage?

Experimental plan : varying composition and heat treatment

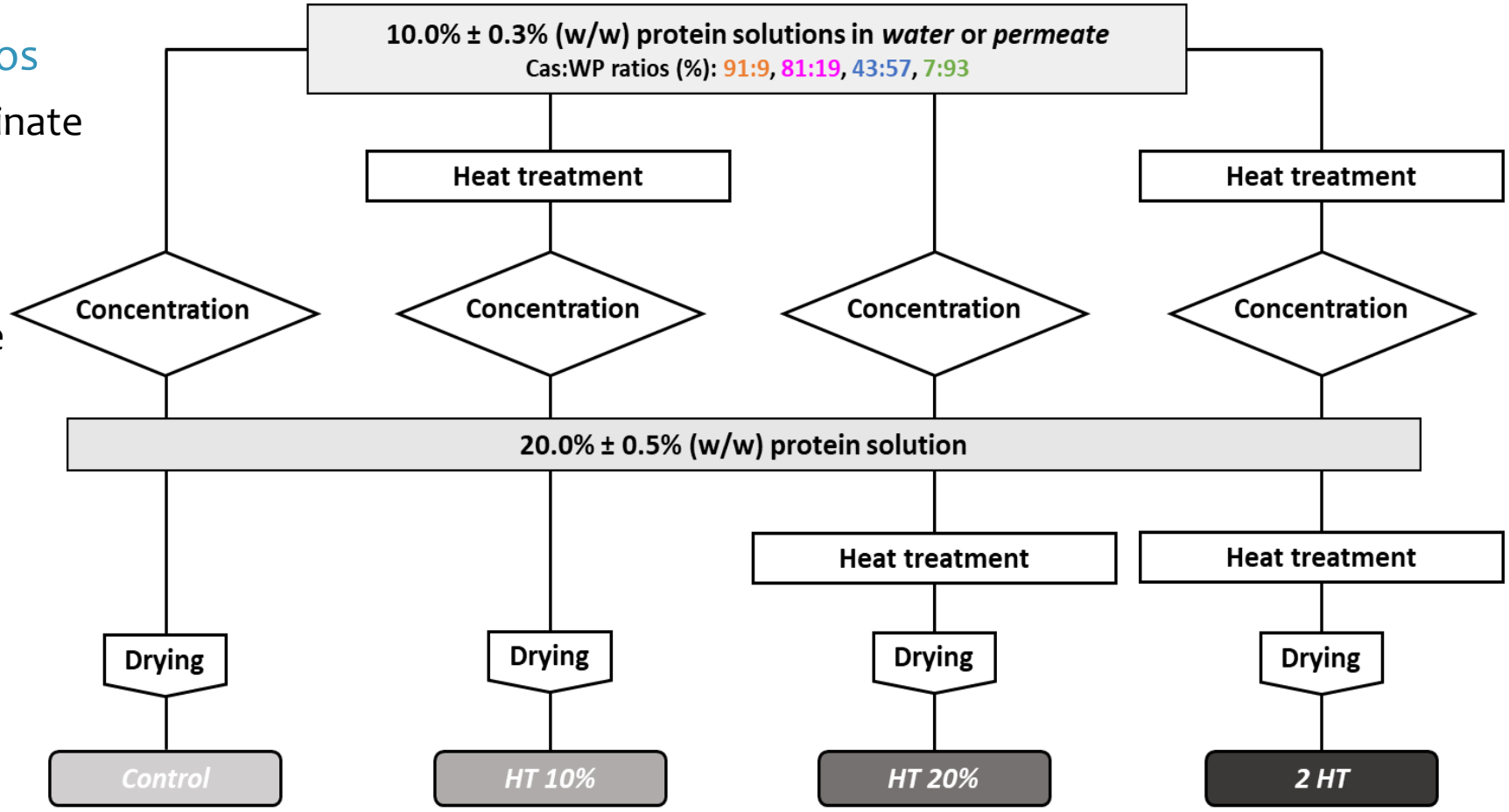
4 Casein : Whey protein ratios

- **91 : 9 :** native phosphocaseinate
- **81 : 19 :** « bovine milk »
- **43 : 57 :** « human milk »
- **7 : 93 :** whey protein isolate

2 Standardizing solutions

- *Water*
- *Permeate*

4 technological routes



Fabrication of powders and their analysis

Fabrication of **powders** at a semi-industrial scale (Bionov)

91:9, 81:19, 43:57, 7:93 x *water, permeate* x *Control, HT 10%, HT 20%, 2HT*

Chemical composition

Total protein content
Whey protein denaturation
β-lactoglobulin molecular state
Lactose content
Total ash content
Color during storage

Physico-chemical properties

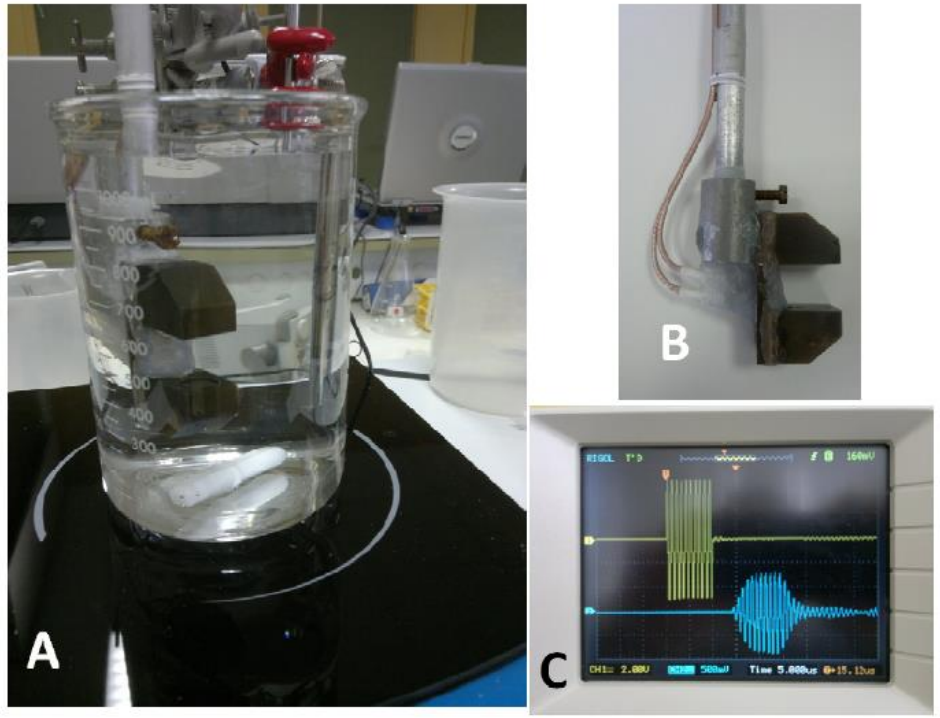
Water activity
Dry matter content
Water sorption isotherm
Particle size
Particle sphericity
Density
Bulk Density

Functional properties

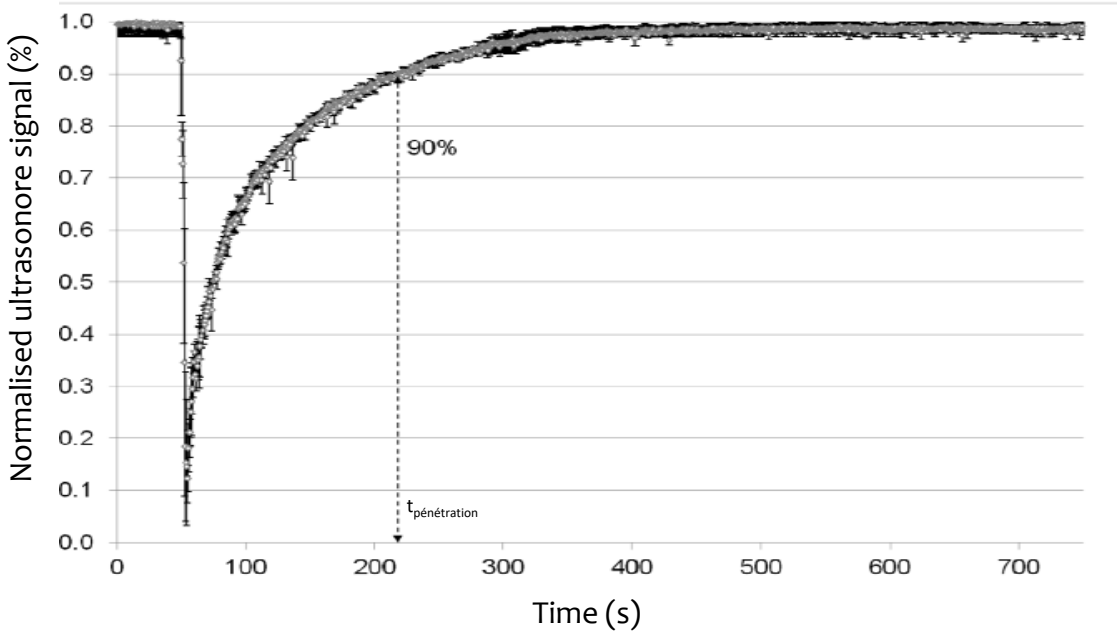
Solubility
Rehydration properties

(Lee et al., 2023)

Determination of penetration time



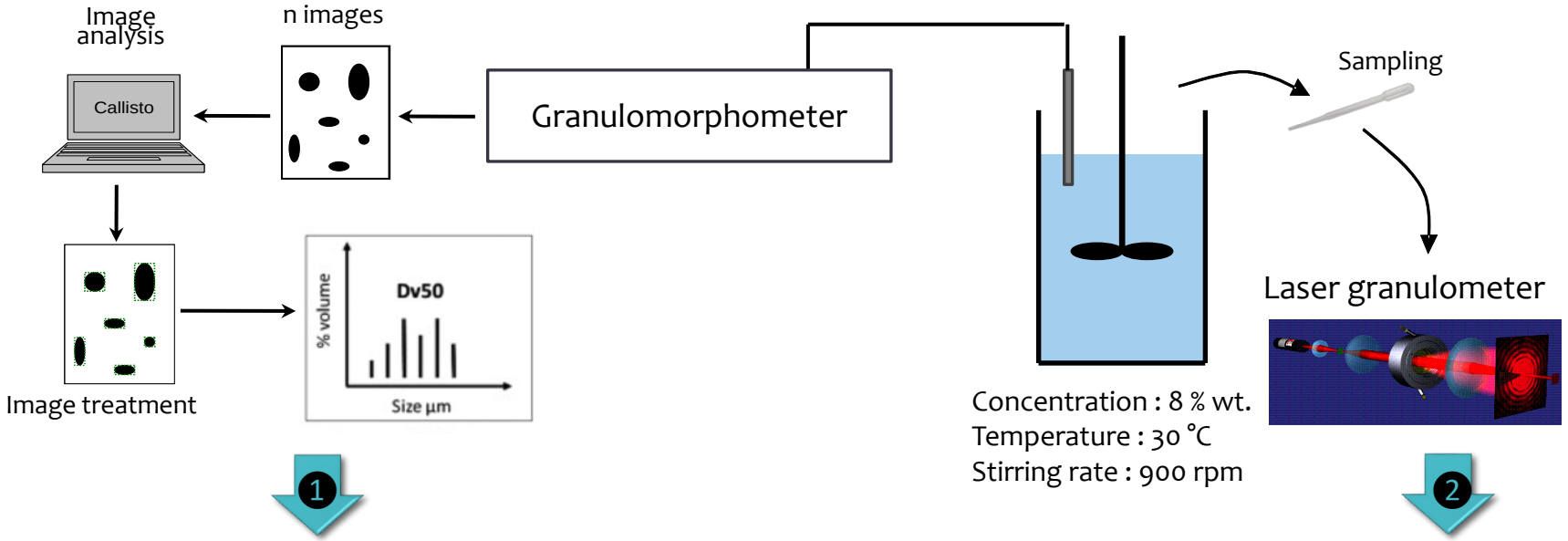
Concentration : 0,2 % wt.
Temperature : 30 °C
Stirring rate : 450 rpm



- Trapped air of powders is replaced by the solvent
- Attenuation of ultrasonore signal by the presence of the solvent medium and any particles in dispersion
- Relaxation of signal measured after introduction of powders

(Richard et al., 2012; Richard et al., 2013)

Determination of fragmentation time / rehydration time



Fragmentation time

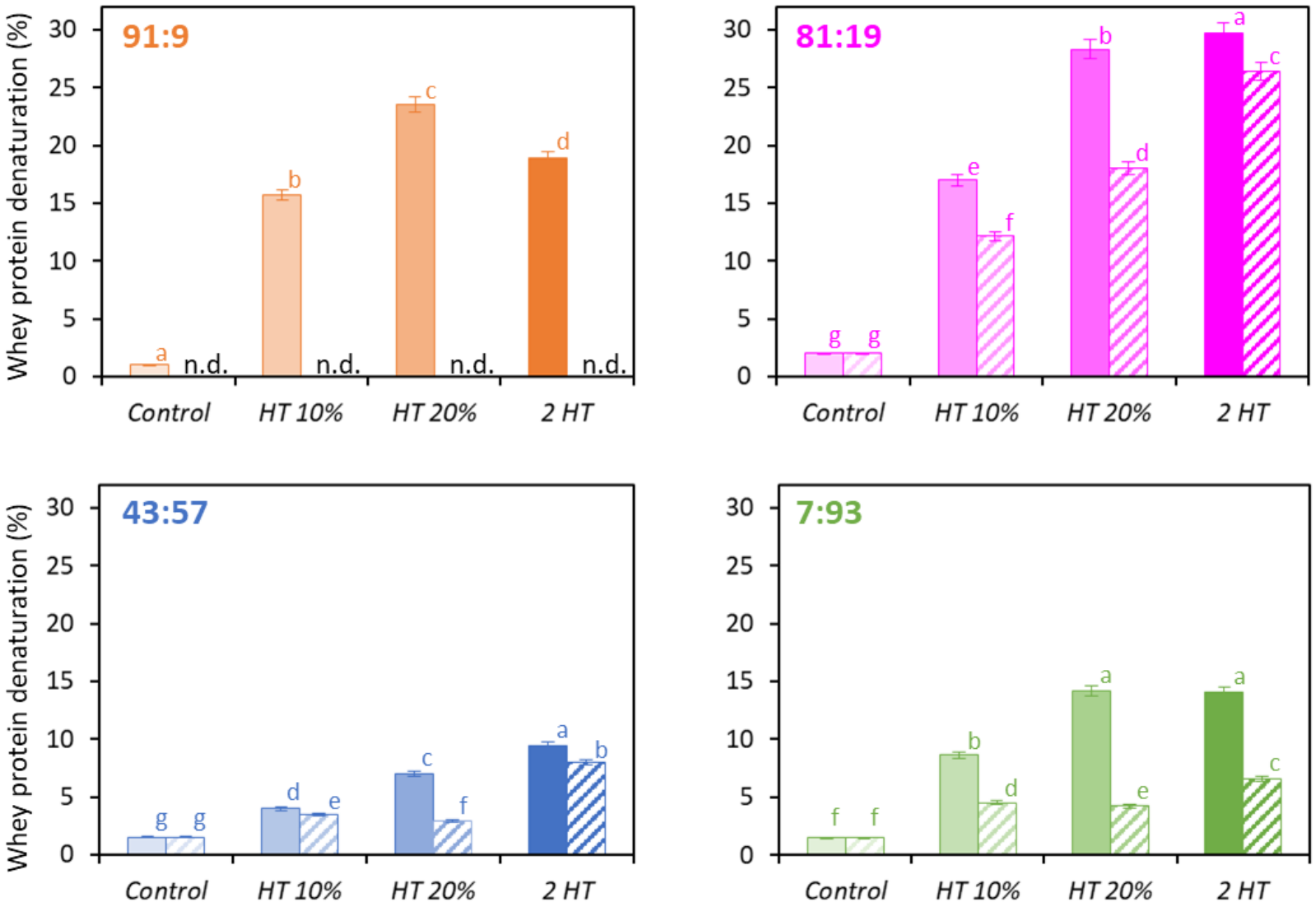
- Analysis of distribution in number of powder particles
- Time for which the number of fragment reaches the maximum

Total rehydration time

- Kinetics of decrease in size (Dv50) during rehydration
- Time for which Dv50 reaches a plateau

(Richard et al., 2012; Richard et al., 2013)

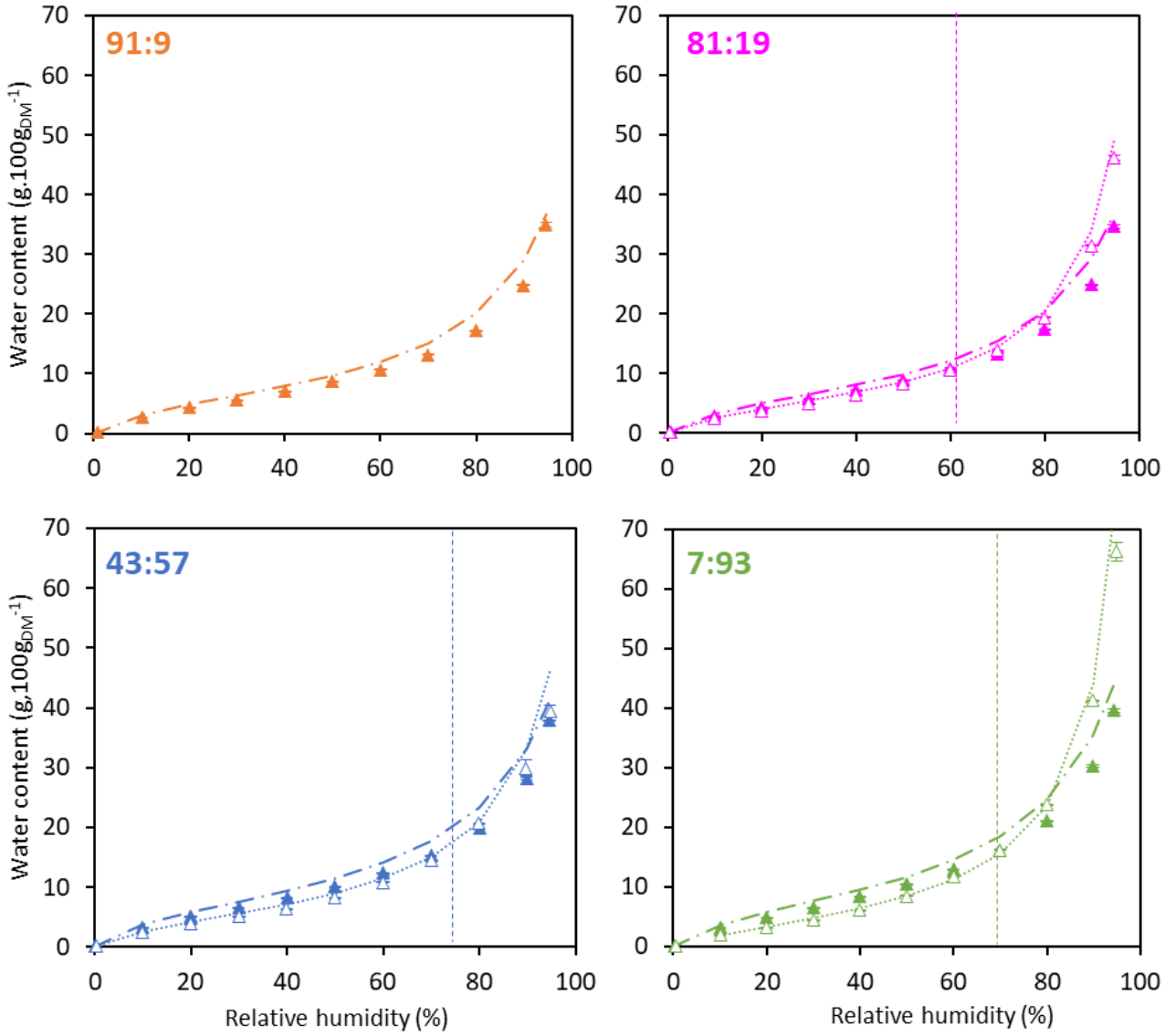
Degree of whey protein denaturation



- Vacuum concentration/spray drying : very low impact on denaturation (< 3 % for *Control*)
- ↑ Total protein content during heat treatment
  -> ↑ denaturation
- Permeate less denaturation than Water : protecting effet of lactose (*Plock et al., 1998*)
- Non cumultaive effect of heat treatment on denaturation

Water sorption isotherm

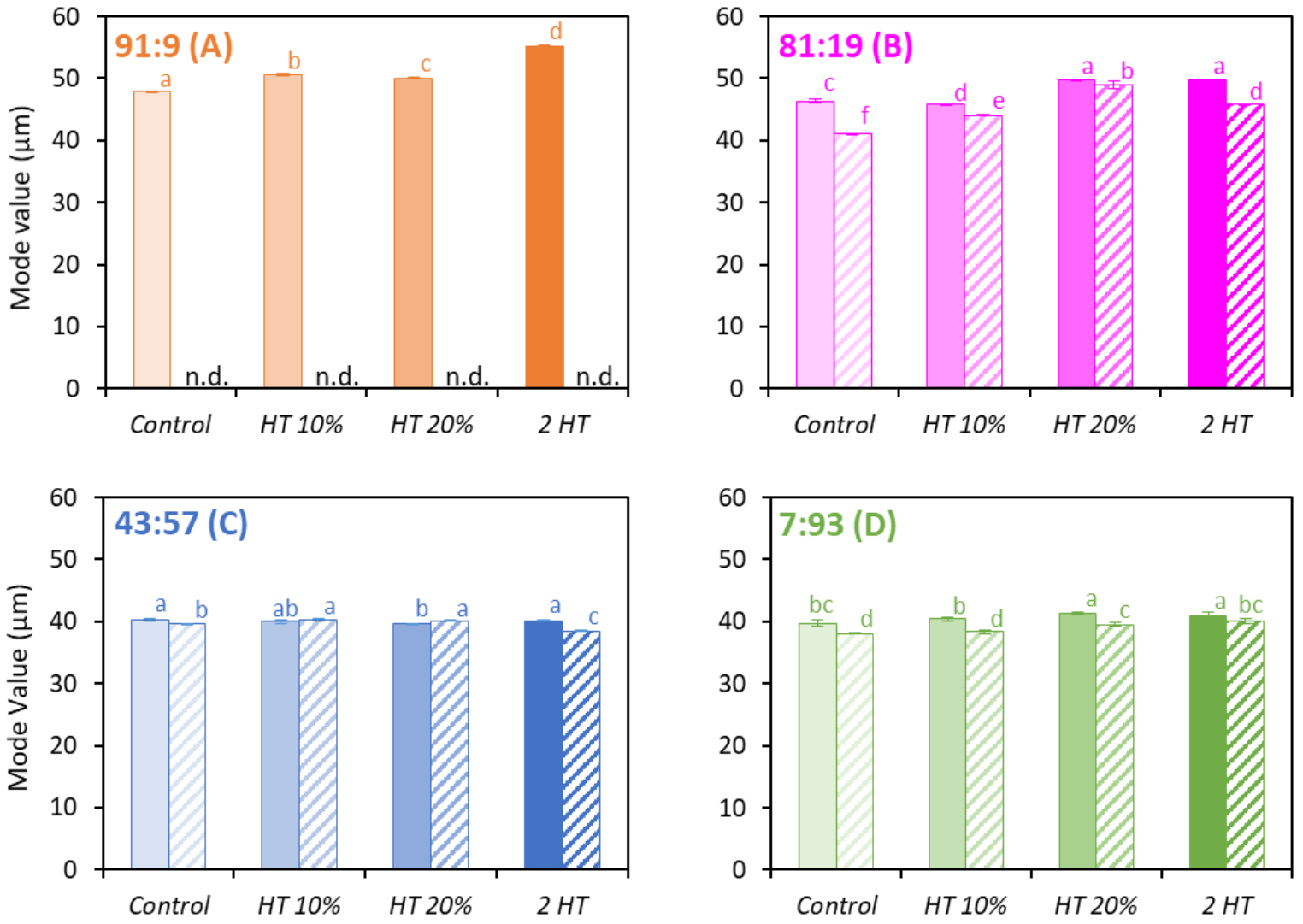
Control — Water / Permeate



- ↑ proportion of whey protein
  -> ↑ hygroscopicity
- *Water vs Permeate* :
  Permeate-based powders were less hygroscopic than the water-based powders until 60-75% RH.

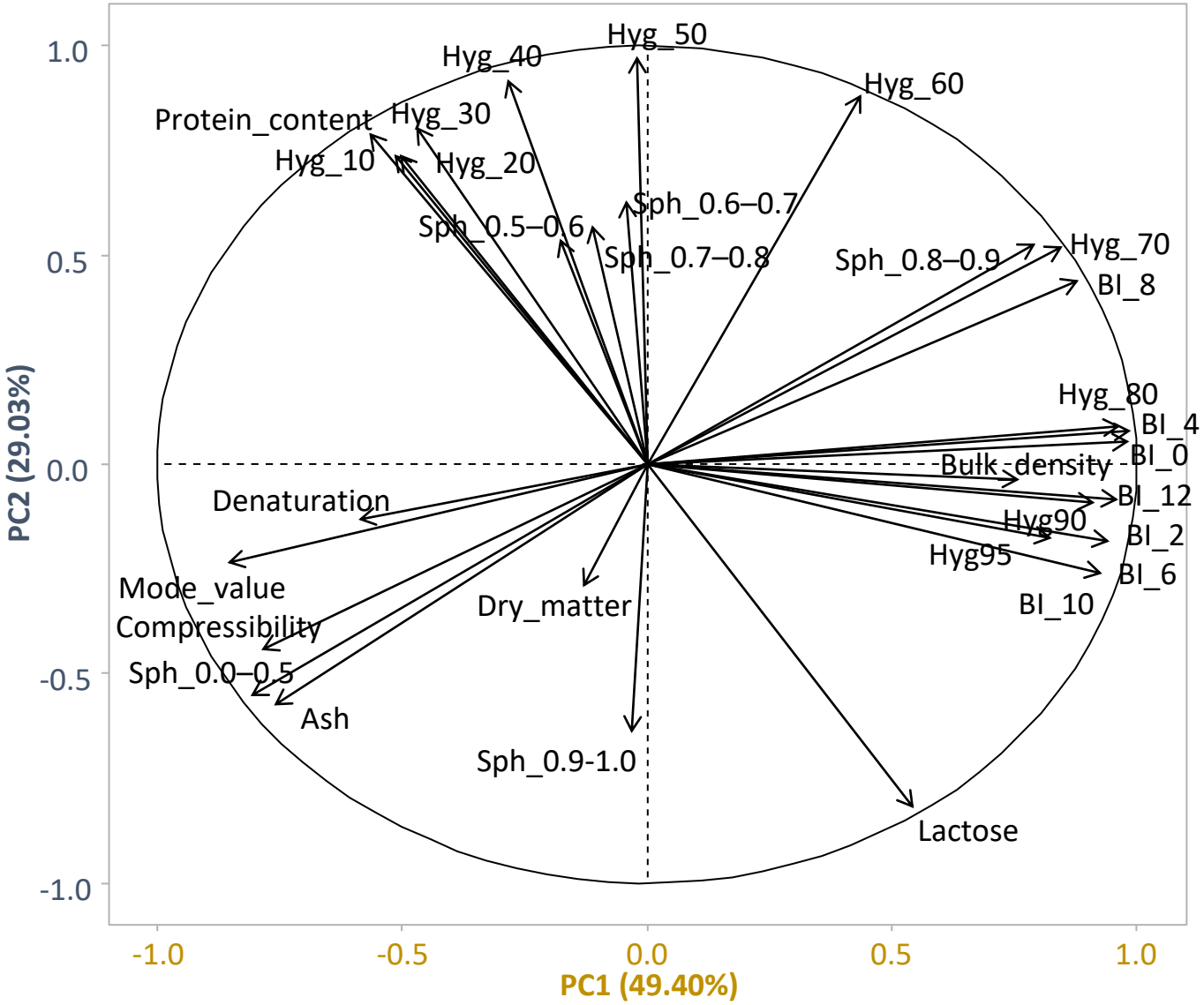
  Water absorbing molecules
  < 50 % RH: proteins
  > 50 % RH : lactose/minerals
  (Berlin, 1968 ; McCarthy et al., 2013)
- No influence of heat treatment on hygroscopicity

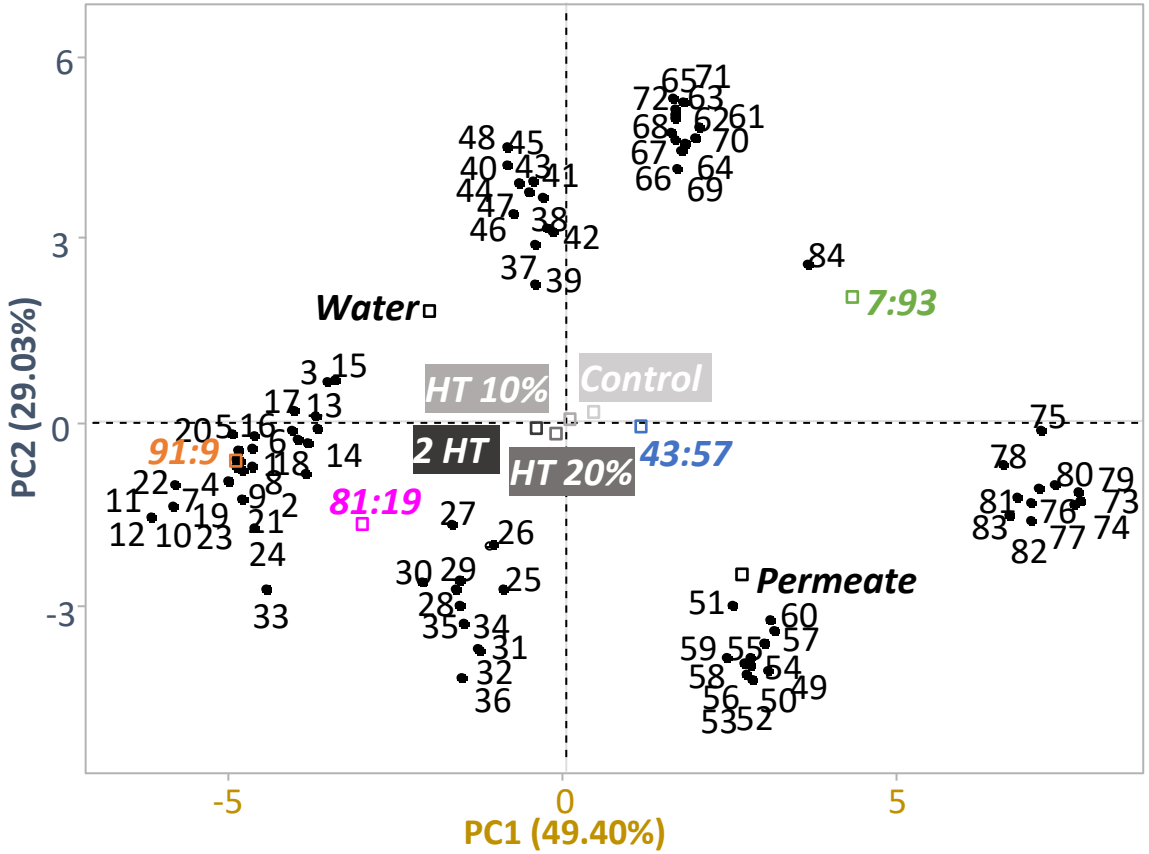
Mode value



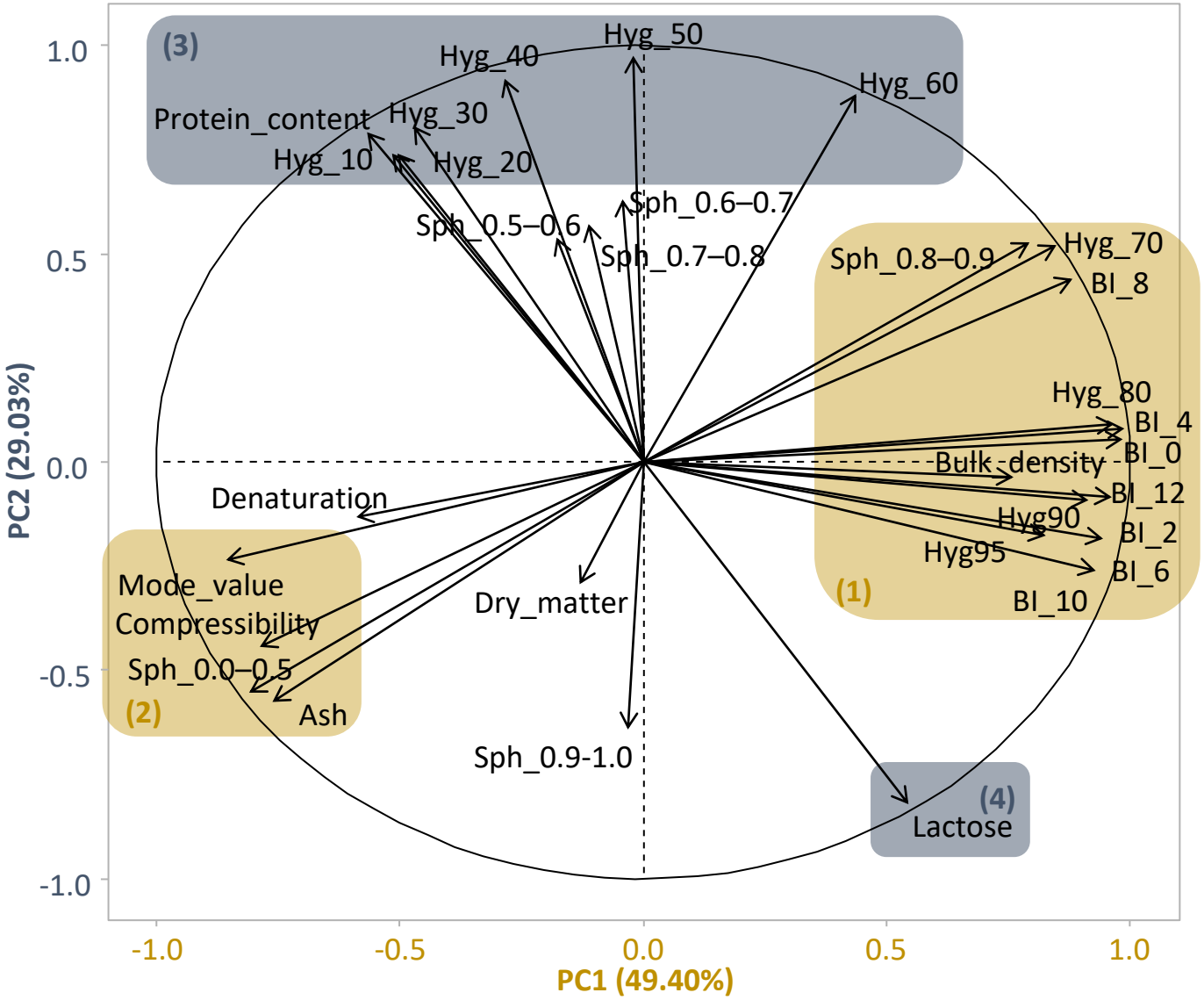
- ↑ proportion of casein -> ↑ mode value
- *Water vs Permeate* : Slight change
- Little impact of heat treatment

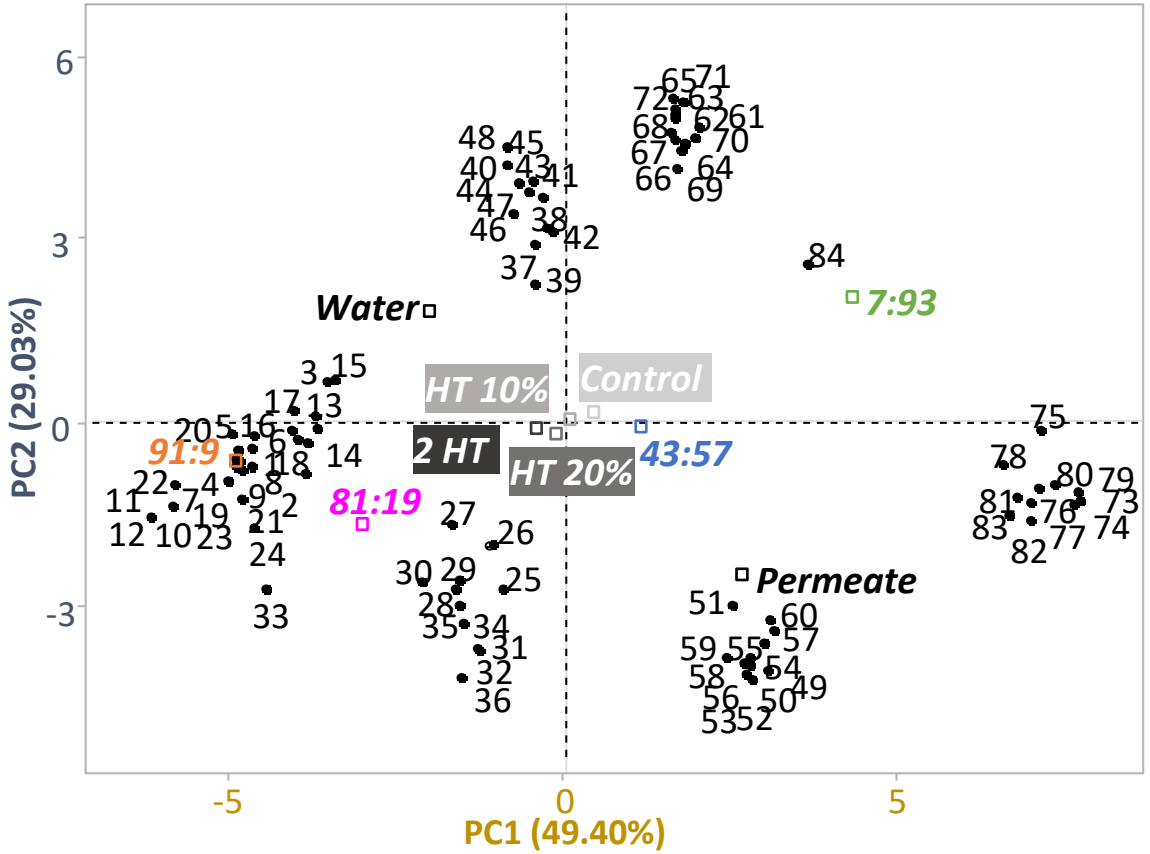
Principal component analysis





Link between composition/heat treatment and properties





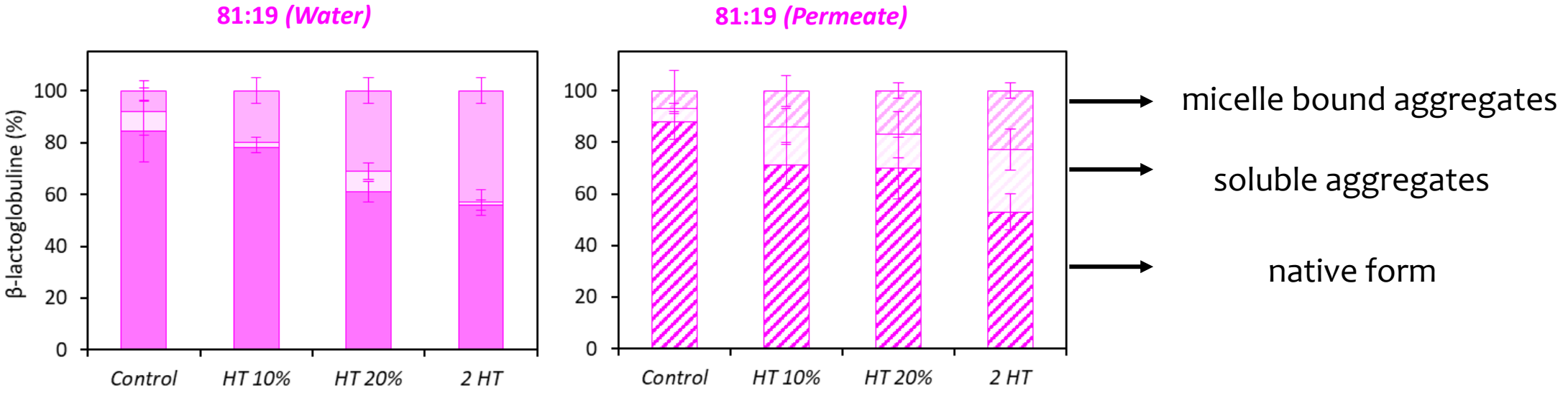
Influence in decreasing order :

Casein:Whey protein ratio

standardizing solution

to much lower extent, heat treatment

Distribution in molecular states of β-lactoglobuline

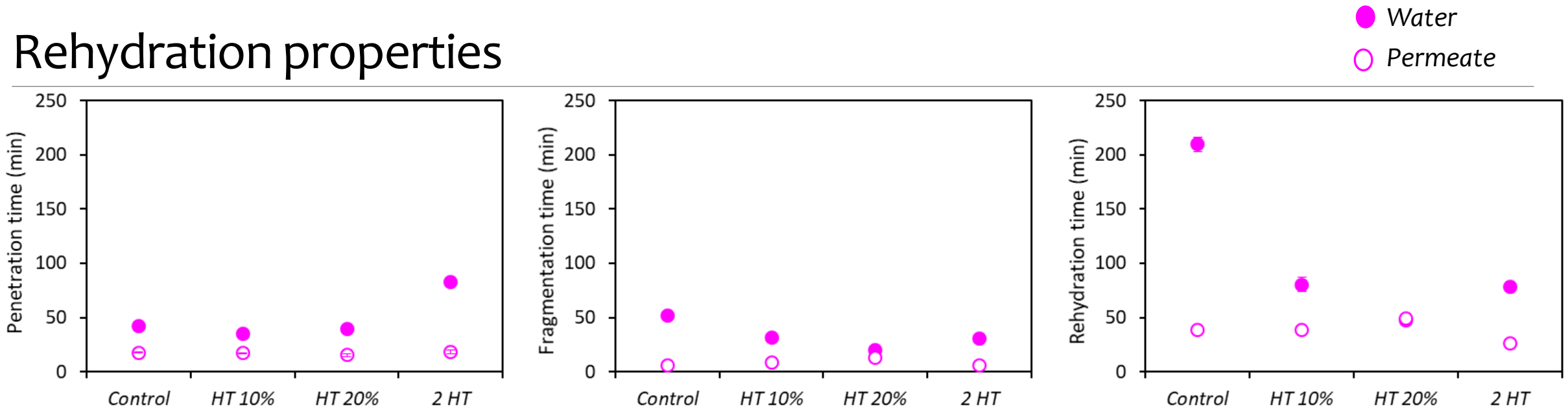


- ↑ heat treatment -> ↑ denaturation/aggregation, especially aggregation of β-lg on the micelles
- This raise is more important than in the literature *(Vasbinder et al., 2020; Oldfield et al., 2020)*;

  concentrated medium, probably the short distance between casein micelles and whey protein promotes their interactions

- *Permeate*: soluble aggregates favored than micelle bound aggregates
- Probability of binding to β-lg is lower; micelles more stable in the presence of lactose *(Williams et al., 2008)*

Rehydration properties



Water :

- Heat treatment -> improves total rehydration =/ Heating during storage reduces rehydration (*Fyfe et al., 2011*)
- Presence of β-lg proteins on the micelles surface = facilitator for the entry of water into the particles and the release of micellar components

Permeate :

- Presence of lactose/ minerals = facilitator of rehydration or solubilization
- ↑ quantity of casein eluted from the particles at the beginning of rehydration was observed -> better micelle solvation in the presence of lactose and minerals

Conclusion

Powders

- ↑ [protein] -> ↑ degree of whey protein denaturation/aggregation
- Concentrates of proteins favor association of casein / soluble protein on the micelle
- Heat treatment effect

Physico-chemical properties

Influence in decreasing order :

- Casein:Whey protein ratio
- Standardizing solution
- *To much lower extent*, heat treatment

Rehydration properties

- Presence of β-lactoglobuline on the micelles surface -> ↓ rehydration time
- Presence of lactose/minerals -> ↓rehydration time

Perspectives

- Confirmation by repetitions of semi-industrial trials
- Principal component analysis on all properties
- Better understanding on evolution of powders during storage

Thank you for listening

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