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# Deciphering the key parameters that influence the rheological properties of milk protein concentrates

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## CONTEXT & AIMS

- ✓ Dairy ingredients with high protein content :
  - high value-added products,
  - increasing demand,
  - specific properties,
  - multitude of applications: cheese, bakery, infant formulae, nutritional products for the elderly and athletes...
- ✓ Rheological properties of protein concentrates greatly modulate the spray drying process and final powder quality, so they must be controlled.
- ✓ Aims :
  - identify the key parameters playing a role in viscosity changes
  - understanding molecular mechanisms that affect the viscosity of high protein concentrates during their manufacture.

## STRATEGY

- Fresh whey proteins (WP) and casein micelles (CM) concentrates (100 g protein.kg<sup>-1</sup>) in osmosed water.
- Mixes: Casein (Cas) to WP of 91:9 (**Cas 91**), 81:19 (**Cas 81**), 43:57 (**Cas 43**) and 7:93 (**Cas 7**).
- 4 different technological schemes (**Fig. 1**) :
  - **Control**,
  - **HT 10%** (74°C/30 s for Cas91-Cas81; 70°C/30 s for Cas43-Cas77)
  - **HT 20%** (74°C/30 s for Cas91-Cas81; 70°C/30 s for Cas43-Cas77)
  - **2 HT** (74°C/30 s for Cas91-Cas81; 70°C/30 s for Cas43-Cas77)
- Samples = concentrates 200 g protein.kg<sup>-1</sup>
- Viscosity 40°C: 1-500 s<sup>-1</sup>

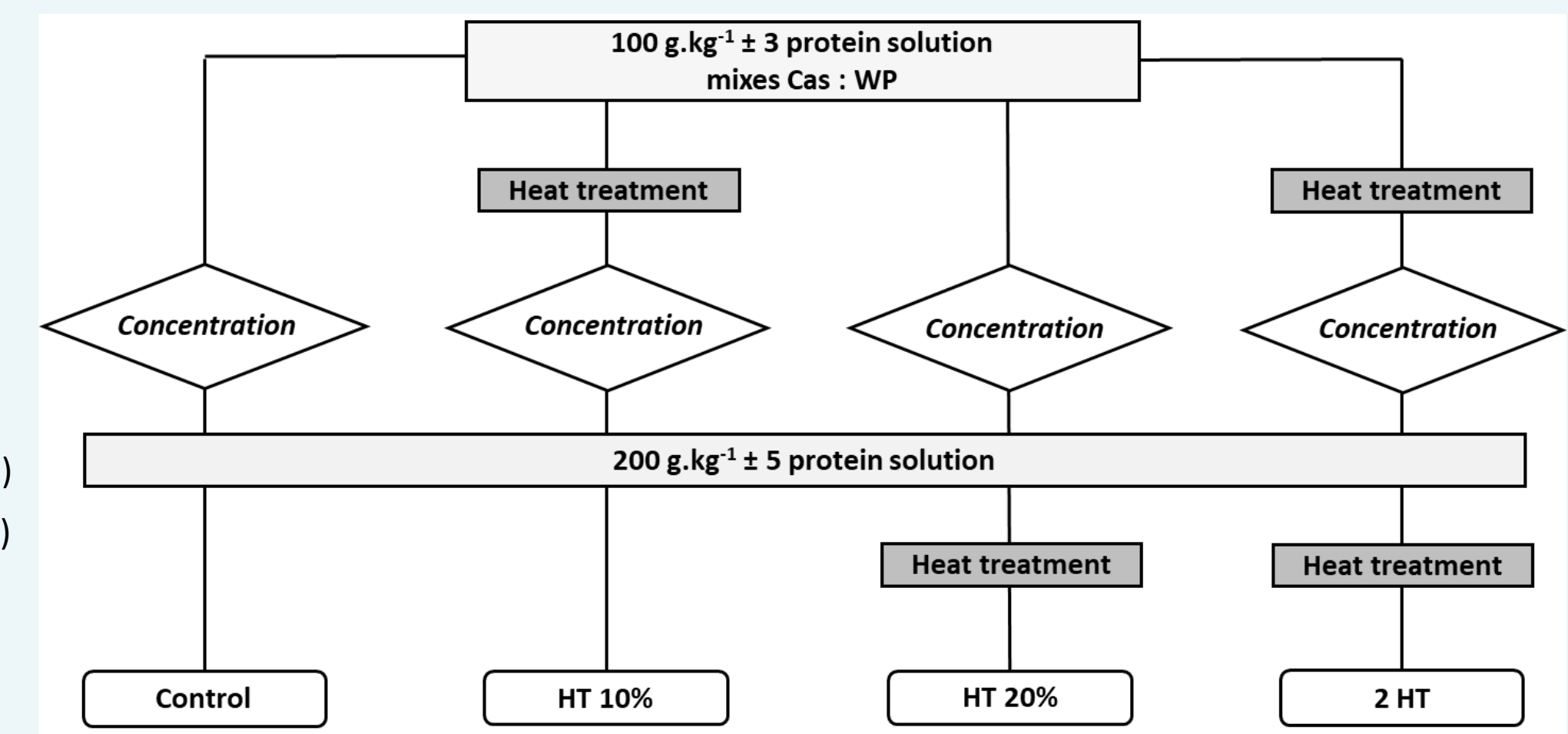
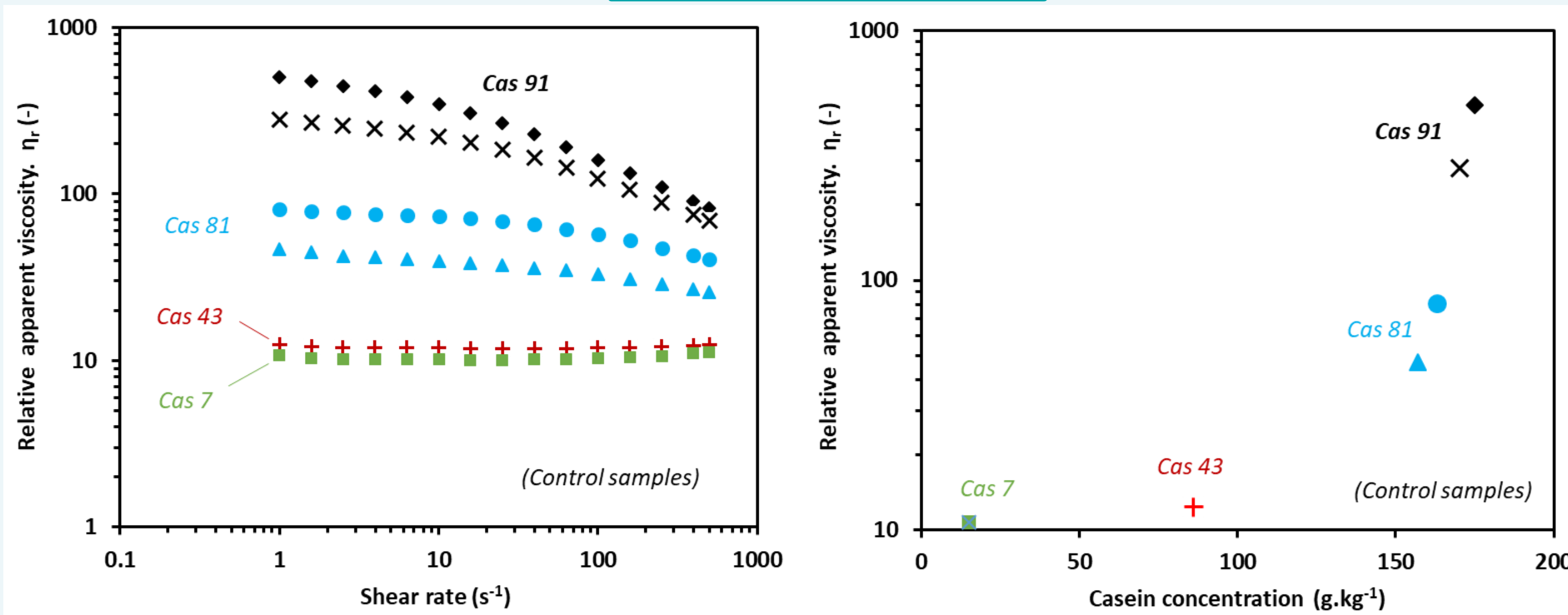


Fig. 1: Different process schemes

## RESULTS

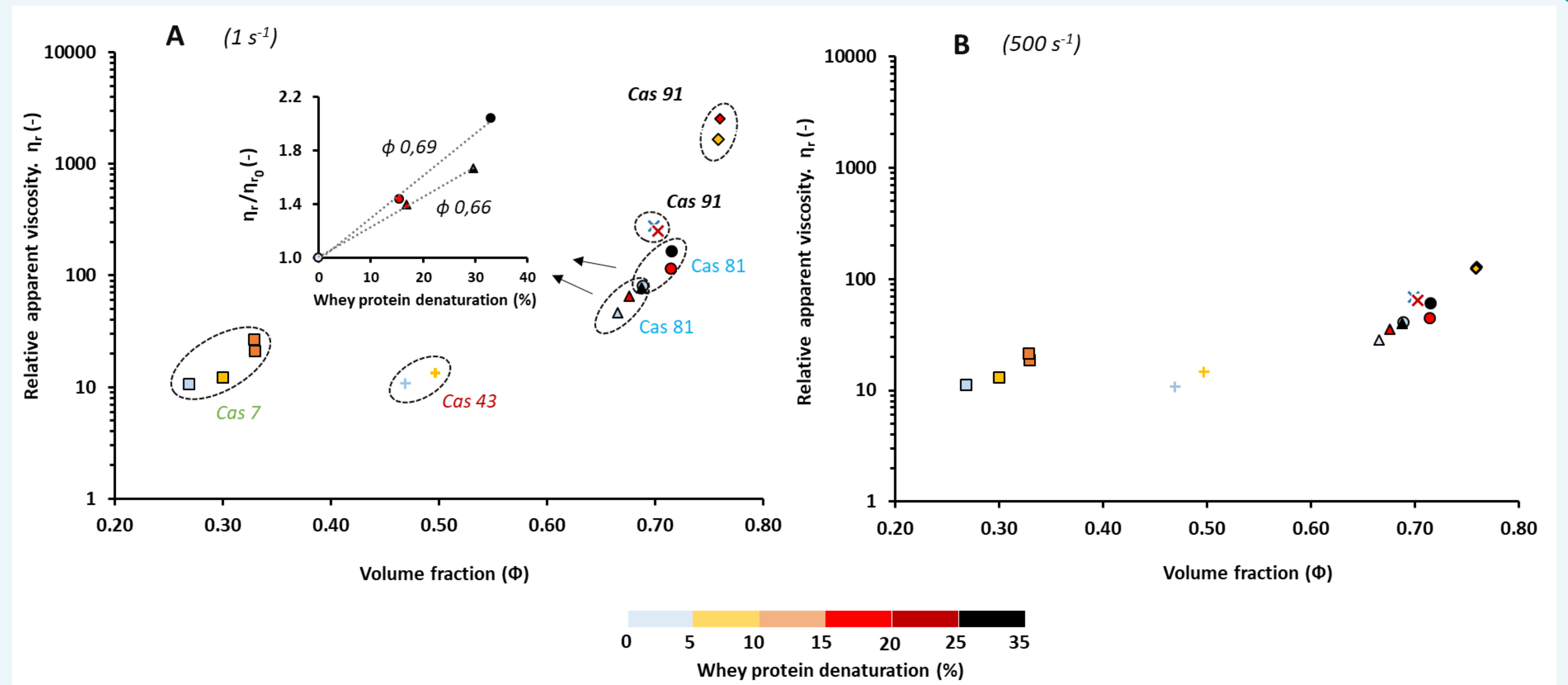
### Impact of Cas:WP ratio



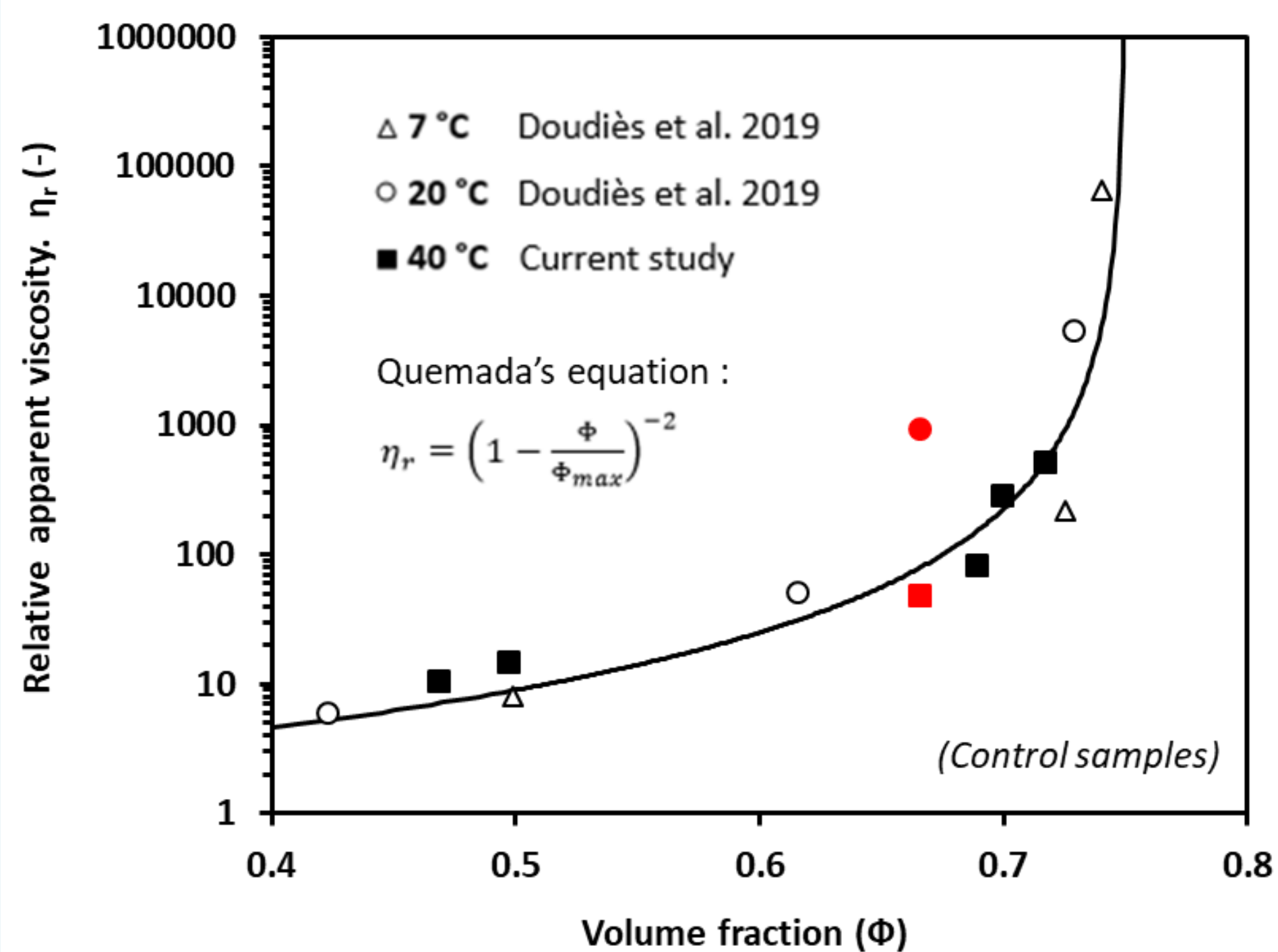
- 1 s<sup>-1</sup>:  $\eta_{r,Cas\ 91} = 50 \times \eta_{r,Cas\ 43}$ ;  $\eta_{r,Cas\ 91} = 8 \times \eta_{r,Cas\ 81}$
- [CM] ↑ ⇒ inter-micelle distance reduction.
  - increased repulsions between CM
  - hindered flow of CM to keep their inter-distances
- Cas 91 and Cas 81 concentrates : shear-thinning behaviour.
  - hindered flow of solvent across particles (at low shear)
  - less hindered at high shear as CM move too

### Impact of WP denaturation level

- Cas 7 : WP denaturation max = 14 % ⇒  $\eta_{r,Cas\ 7\ heat\ treated} = 2 \times \eta_{r,Cas\ 7\ untreated}$ 
  - water holding capacity of denatured WP > native WP (**A**).
- Cas 81 : linear increase of the viscosity with the WP denaturation (inset **A**).
  - formation of large aggregates with irregular shapes, i.e. CM-WP complexes and soluble aggregates ⇒ ↓ packing density and ↑ viscosity.
- Cas 91 :
  - concentrates with  $\Phi=0.70$  ⇒ no viscosity differences between untreated and heat-treated concentrates.
  - $\Phi=0.76$ , ↑ (11%) in the WP denaturation level ⇒ ↑ (52%) in viscosity (**A**).
- The increase in viscosity induced by the heat-treatment was smaller at higher shear rates than at low shear for Cas 81 and Cas 91 (**B**).



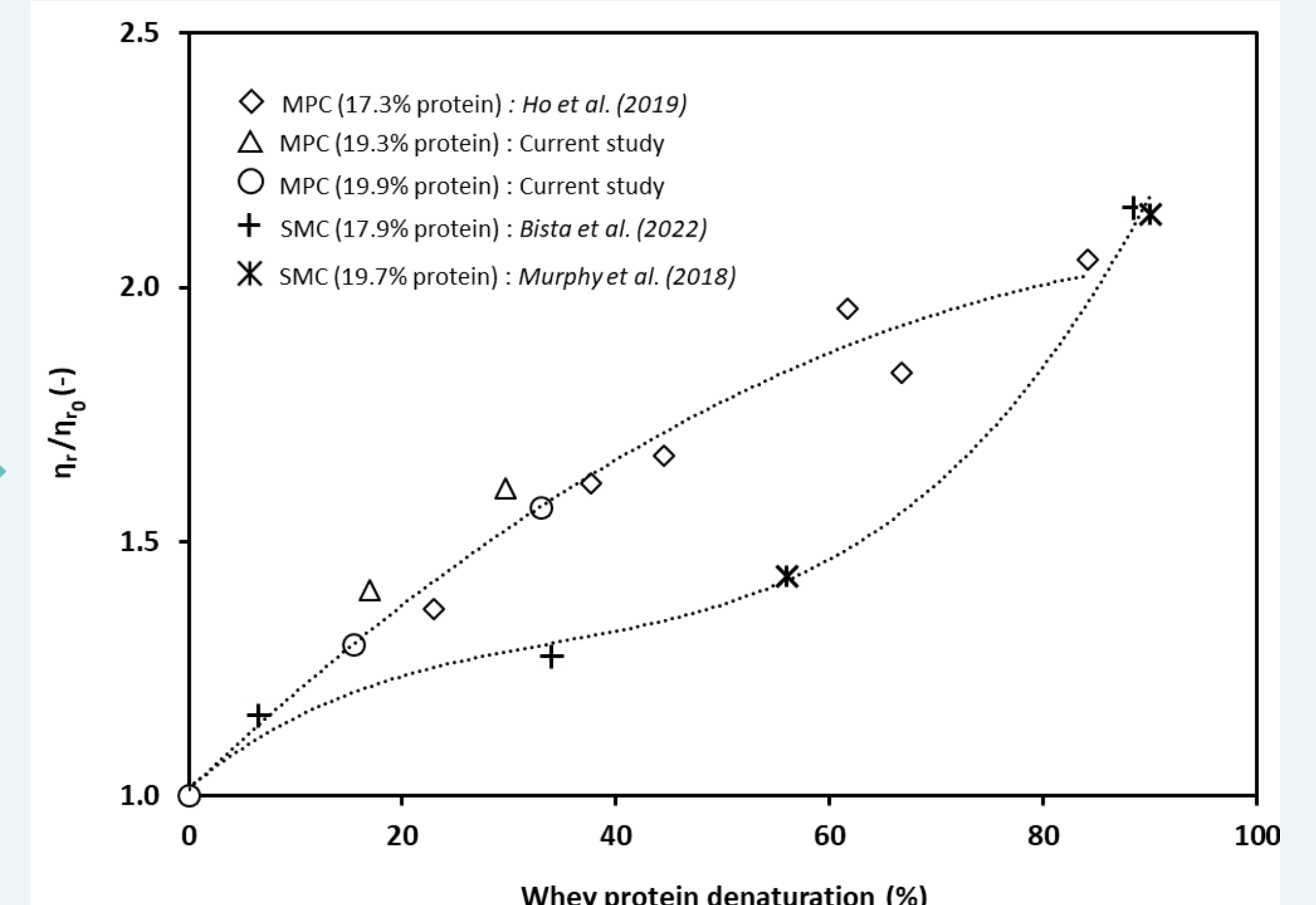
### Impact of temperature



- $\eta_r = f(\Phi)$
- $\Phi_{max} = 0.75$  i.e.  $[casein]_{max} = 192\ g.L^{-1}$
- Same  $\Phi$  but different  $\eta_r$  (red samples) : Cas:WP ratio? soluble components? mineral content?...

- MPC (milk protein concentrate) ⇒ logarithmic trend
- SMC (skim milk concentrate) ⇒ exponential trend
- Below 85 % of WP denaturation : ratio  $\eta_r/\eta_{r0}$  ⇒ MPC > SMC
  - MPC : heat treatment at high protein content ≠ SMC : heat treatment at low protein content (milk before evaporation) ⇒ The protein content during a heat treatment is known to affect the type of aggregates formed.

### Impact of concentrate type



## CONCLUSION & PERSPECTIVES

- This study shows the influence of 3 key parameters, i.e. Cas:WP ratio, WP denaturation level and temperature, on the rheological behavior of dairy protein concentrates at 40°C, a relevant temperature for the spray-drying process (atomization step) :
  - Cas 7 and Cas 43 ⇒ Newtonian behavior / Cas 81 and Cas 91 ⇒ shear-thinning behavior ; Cas 91 ⇒ highest viscosity.
  - Changes in viscosity of concentrates induce by the heat treatment depend of the WP denaturation level, the Cas:WP ratio and the concentrate type.
  - $\eta_r = f(\Phi)$  according to Quemada's equation regardless of the temperature and  $\Phi_{max} = 0.75$ , nevertheless the Cas:WP ratio (i.e. protein size diversity) seems to modulate this relation.
- Relations between rheological behavior of concentrates and physical properties of powders such as particle size, density... should be investigated in a future work.