Deciphering the key parameters that influence the rheological properties of concentrated milk protein systems using a multifactorial approach

Francois Martin, Florence Rousseau, Jeehyun Lee, Gaëlle Tanguy, Emeline Gousse, Marie-Hélène Famelart, Romain Jeantet, Cécile Le Floch-Fouéré

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

François Martin[1,2], Florence Rousseau[1], Jeehyun Lee[1], Gaëlle Tanguy[1], Emeline Goussé[1], Marie-Hélène Famelart[1], Romain Jeantet[1] and Cécile Le Floch-Fouéré[1]

[1] INRAE, Institut Agro, STLO, 35042 Rennes, France ; [2] CNIEL, 75009 Paris, France

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

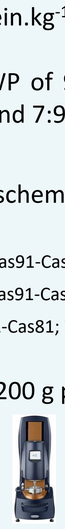
➢ Fresh whey proteins (WP) and casein micelles (CM) concentrates (100 g protein.kg^{-1}) in osmosed water.

➢ 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^{-1}

➢ Viscosity 40°C: 1-500 s^{-1}



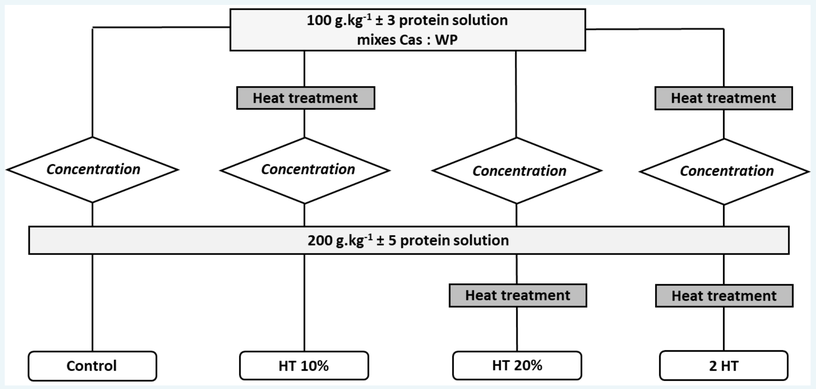
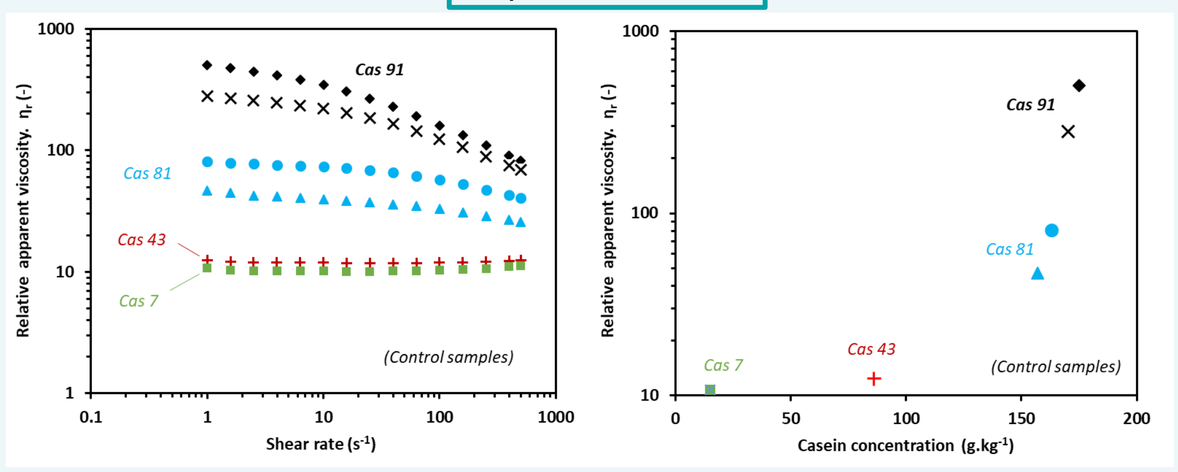


Fig. 1: Different process schemes

RESULTS

Impact of Cas:WP ratio



➢ 1 s^{-1} : $\eta_{rCas\ 91} = 50 \times \eta_{rCas\ 43}$; $\eta_{rCas\ 91} = 8 \times \eta_{rCas\ 81}$

➢ [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

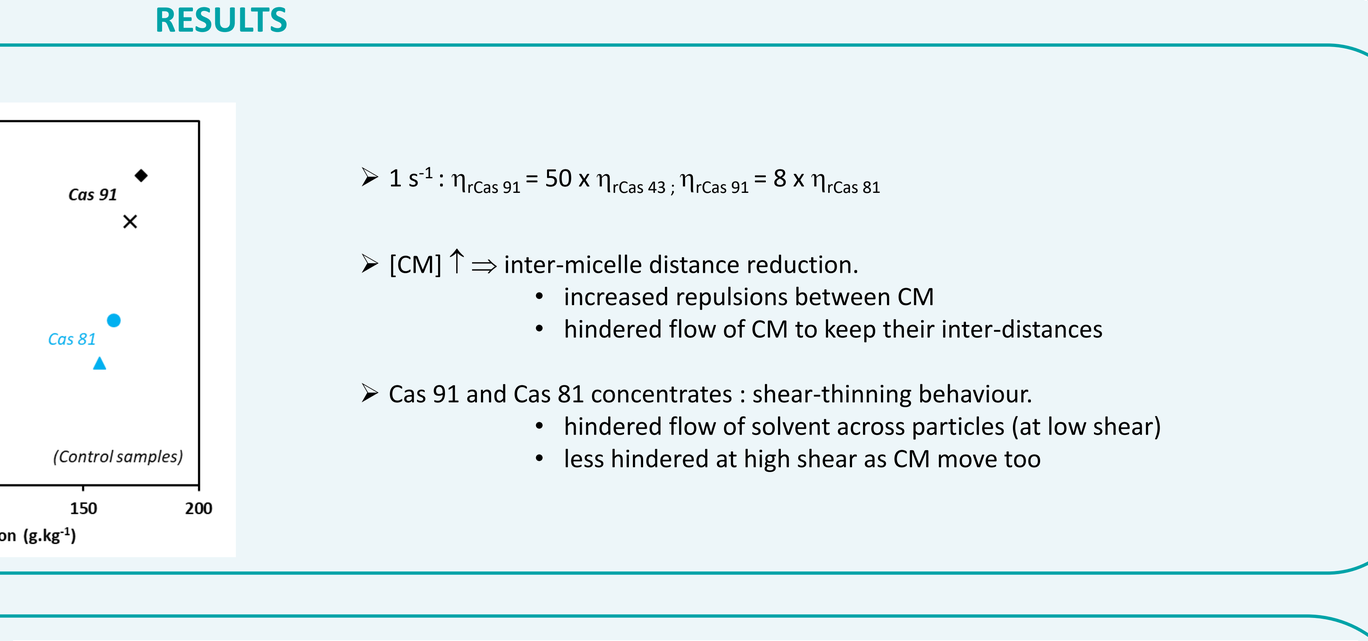
Impact of WP denaturation level

➢ Cas 7 : WP denaturation max = 14 % ⇒ $\eta_{rCas\ 7\ heat\ treated} = 2 \times \eta_{rCas\ 7\ untreated}$
- water holding capacity of denatured WP > native WP **(A).**

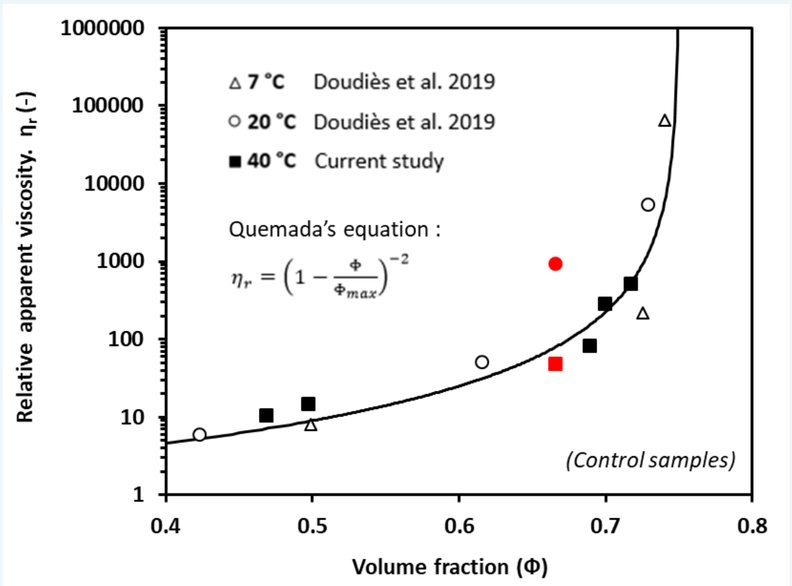
➢ Cas 81 : linear increase of the viscosity with the WP denaturation (inset **A**).
- formation of large aggregates with irregular shapes, *i.e.* CM-WP complexes and soluble aggregates ⇒ ↓ packing density and ↑ viscosity.

➢ Cas 91 :
- concentrates with Φ=0.70 ⇒ no viscosity differences between untreated and heat-treated concentrates.
- Φ=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



➢ $\eta_r = f(\Phi)$

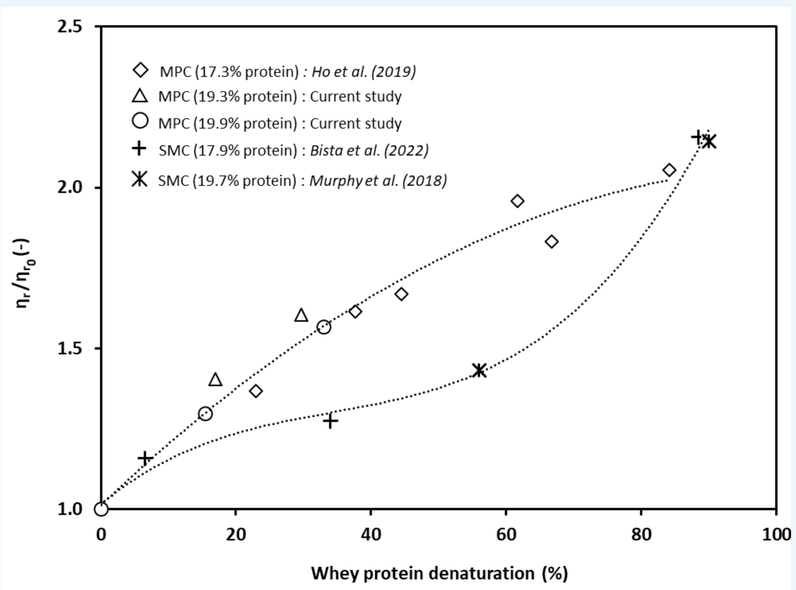
➢ $\Phi_{max} = 0.75$ *i.e.* $[casein]_{max} = 192$ g.L^{-1}

➢ Same Φ but different η_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 η_r / η_{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.

Centre
Bretagne - Normandie

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65 rue de Saint Brieuc
35 042 Rennes Cedex
francois.martin@inrae.fr