Drainage of acid-rennet gels from preheated milk

Marie-Hélène Famelart, Islem Mtibaa, Florence Rousseau, M Perrignon, R Richoux, Corinne Rondeau-Mouro, Patrice Gaborit

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IDF Cheese Science & Technology Symposium

CONTEXT & AIM

- ✓ **In France, Fresh cheese production from cow's and goat's milk accounts for 600,000 tonnes a year (source: L'économie laitière en chiffres, 2019).**
- ✓ **There is very few published work on the drainability of acid-rennet curds. Little data is available on the effect of technological factors on the draining capacity of the latter gels.**
- ✓ **Some studies on the effect of milk preheating, but virtually none on its effect on gel drainage**
- ✓ **The main aim of this work was to study the effect of 2 preheating treatments of milk on acid-rennet induced gelation and drainage**

STRATEGY

Raw skim milk → Pasteurization 72°C-20s (lowH)-whey protein denaturation=8±4 % / Heat treatment 95°C-120s (highH)-whey protein denaturation=74±3 %

2.1 kg milk (25°C) + 0.0525 DCU of mesophilic starter MA16 (Danisco) + CHY-MAX + (200 IMCU)-30 min later

Gelation → **Acid-rennet gel pH 4.6**

Stirring

DHR-2 rheometer (TA Instruments) + Couette cylinder at 25°C + covered by paraffin oil
1- Time sweep (15 h, till pH 4.6)
γ: strain amplitude=0.1 %
f: frequency=1 Hz
2- Frequency sweep
γ=0.1 %- f=100-0.01 Hz
3- Strain sweep
f=1 Hz-γ=0.1-200 %
t_{gel} and pH_{gel} when G'=1 Pa

Drainage

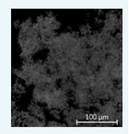
Centrifugation for 3-30 min

140 g gel 2800 *g*-25 °C

Lab-scale pilot- 25 °C-24 h

Analyses

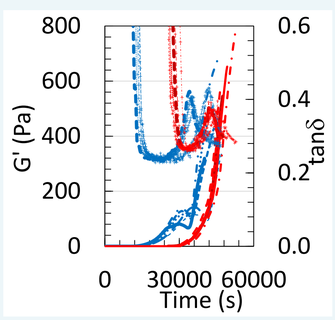
- *Weights of drained whey,*
- *Dry matter of gels,*
- *Rheological behaviour of gels*
  - ✓ *Upper cross-hatched plate (∅=40 mm) for gels drained by centrifugation*
  - ✓ *Both cross-hatched plates for gels drained on the pilot*
  - ✓ *Normal force of ca. 0.1 N*
  - ✓ *Low amplitude oscillation γ=0.1 %, f=100-0.1 Hz*
  - ✓ *Large amplitude oscillation γ = 0.1-200 %, f=1 Hz*
- *Microstructure by confocal microscopy using Fast Green*
- *Image analysis: mathematic morphology by using gray morphology, D. Legland (INRAE, Nantes) with Fiji*

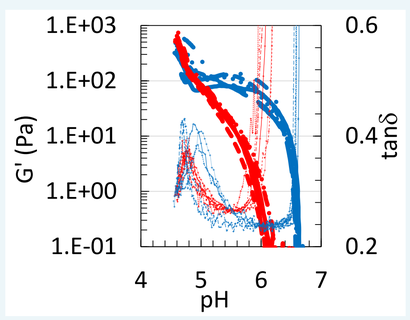


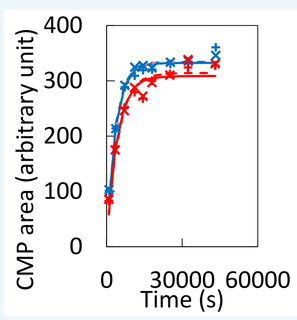
+ CMP hydrolysis (HPLC, method adapted from Bauland et al. (2020))

RESULTS

1. Formation of acid-rennet gel



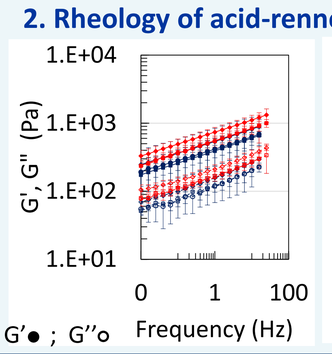


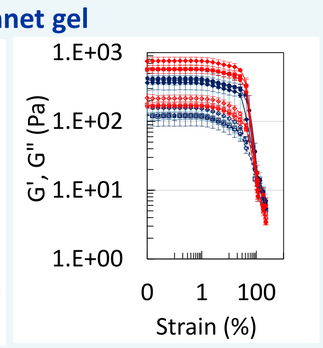


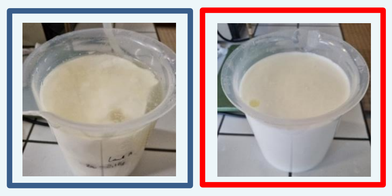
	LowH	HighH
t_{gel} (min)	233±9	493±27
pH_{gel}	6.56±0.02	5.87±0.06
$G'_{at\ pH\ 4.6}$ (Pa)	419±73	560±137
$tan\delta_{max}$	0.41±0.00	0.38±0.01
$tan\delta_{pH\ 4.6}$	0.30±0.01	0.30±0.01

HighH treatment:
- *slows down the gelation kinetics: longer t_{gel} and lower pH_{gel}*
- *slightly increases $G'_{at\ pH\ 4.6}$*
- *reduces the $tan\delta_{max}$ (less structure rearrangements over time of the gel)*

2. Rheology of acid-rennet gel

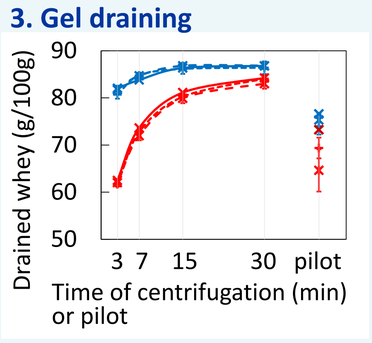


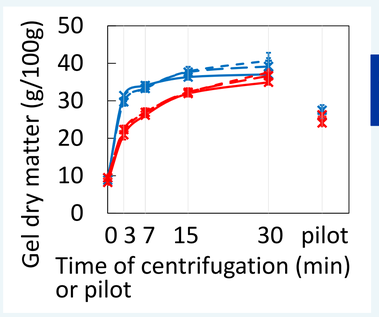




- *Elastic dominant gels*
- *HighH treatment reduces the gel syneresis*

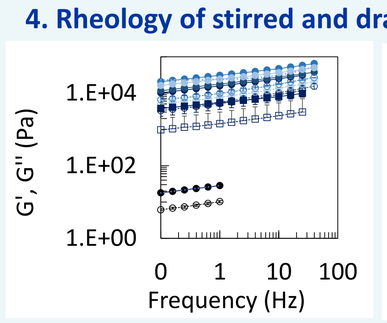
3. Gel draining

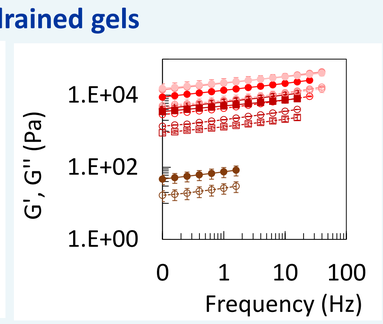


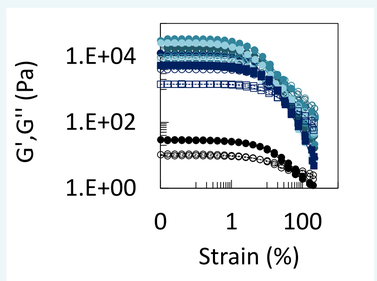


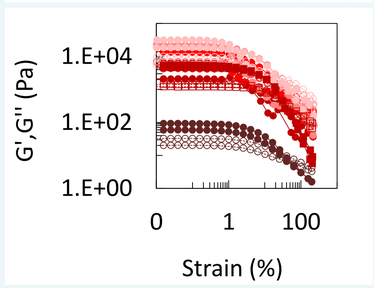
HighH treatment reduces the gel draining

4. Rheology of stirred and drained gels



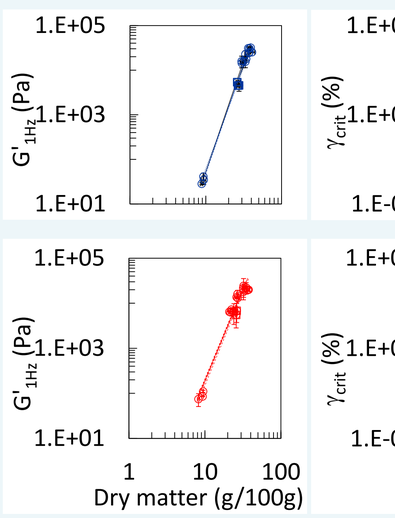


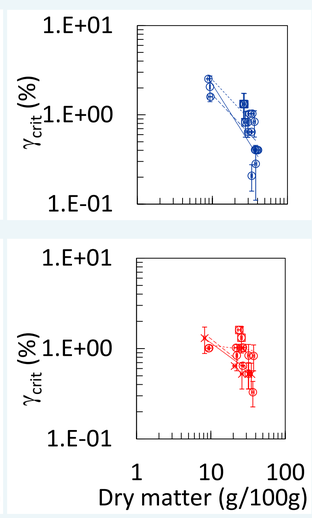




- *Elastic dominant gels*
- *G' lowH > G' highH (but more drainage in lowH gels)*
- *Yielding of type I, i.e. just strain thinning (according to the classification of Hyun et al. (2011, Progress Polymer Science **36**))*

G' ●; G'' ○ ; darker to lighter colours for increasing time of centrifugation
G' ■; G'' □ ; gel drained on the pilot





G'~[dry matter]$^{\alpha}$
Slope of [γ_{crit} ~ dry matter] < 0

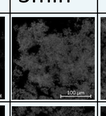
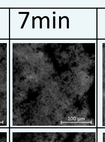
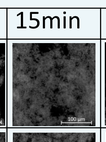
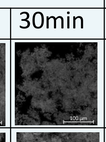
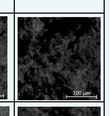
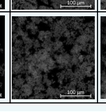
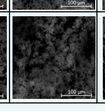
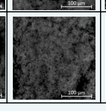
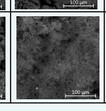
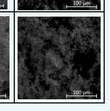
⇒ **Strong-link model =**
inter-microgel interactions > intra-microgel interactions
(Shih et al. (1990, Phys. Rew. A, **42**))

$G' \propto C^{(3+x)/(3-D_f)}$
$\gamma_{crit} \propto C^{-(1+x)/(3-D_f)}$
with D_f = fractal dimension

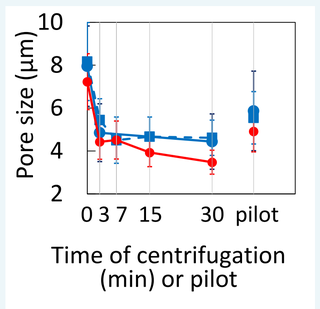
	LowH	HighH
α	4.76±0.21	4.08±0.02
D_f	2.13±0.04	1.98±0.07

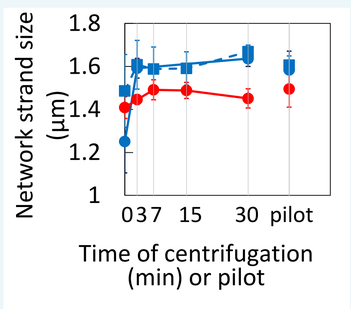
α values in agreement with others:
- *Zhong et al. (2004, Langmuir, **20**), Andoyo et al. (2015, Food Hydrocoll, **51**);*
- *Df values in agreement with others:*
  - ✓ *Acid or rennet gel, Df=2.20, Bremer et al. (1989, J. Chem. Faraday Trans., **85**);*
  - ✓ *Rennet casein gel, Df=2.00-2.30, Vétier et al. (2000, J. Dairy Sci., **86**) ;*
  - ✓ *Casein acid gel Df=2.5-2.7, Andoyo et al. (2015, Food Hydrocoll, **51**).*
- *Higher α value for lowH gels;*
- *Higher Df value for lowH gels*

5. Microstructure of stirred and drained gels

	Stirred				Pilot
		3min	7min	15min	30min	
LowH						
HighH						

Protein network = white; pores = black





- *The stirred gels = fluffy network (large microgels floating in whey) ≈ stirred yoghurt;*
- *Drainage = reduction in the size of pore zones + increase and densification of the network*
- *HighH treatment reduces pore and network strand sizes as compared to lowH treatment.*

CONCLUSIONS & PERSPECTIVES

About acid-rennet gels

- **Acid-rennet gels before and after their drainage are elastic dominant gels with few interactions between protein building blocks;**
- **But Interactions between protein building blocks (# microgels) were stronger than interactions inside protein building blocks;**

About the effect of the heat treatment

- **The highH treatment of skim milk (95°C-120 s), as compared to the lowH treatment (72°C-20s), slows down milk gelation and leads to a gel less prone to structure rearrangements over time, due to the presence of whey protein aggregates, as in the rennet gelation of preheated milk;**
- **Consequently, the drainage of highH gels was reduced and drained gels were less packed.**

This study has allowed to:

- **Develop methods to follow the drainage and the properties of drained gels ;**
- **Better understand the drainage of these gels.**

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