Monitoring dairy protein aggregate structure allows to control the texture of emulsions

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Connectivité des gouttes de matière grasse par des agrégats protéiques et texturation des émulsions

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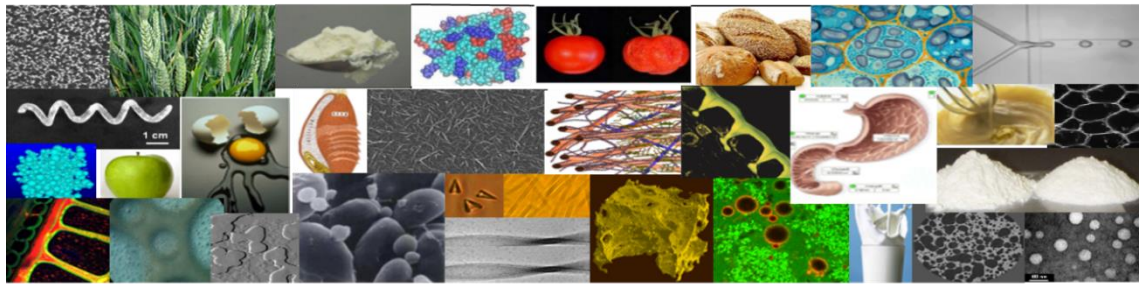


Industrial context

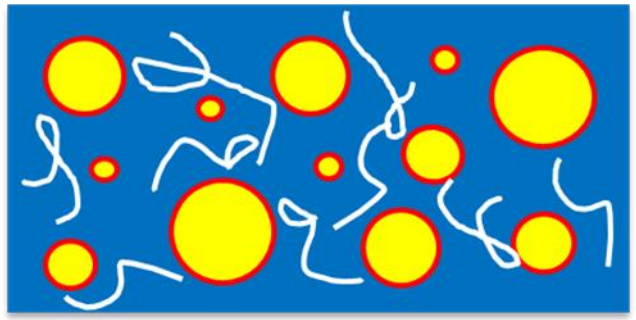
Texturize dairy emulsions

Acidified sytem → caseins

Neutral pH → **additives**

CLEAN LABEL

100% dairy products



Gelling and thickening agents texture the **continuous** phase and trap the oil droplets

O/W emulsion

Scientific context

Background

- ✓ Native whey proteins (NWP) have excellent emulsifying properties (Dickinson, 1999)
- ✓ NWP are sensitive to heat treatment and can form aggregates with different shapes and sizes after heating (Nicolai, 2011)
- ✓ Pure aggregates are not able to form small droplets and stable emulsions whereas by mixing with NWP, droplet size, stability and texture of emulsions can be controlled by modulating the **connection between droplets** (Surel, 2014).

↓

- ✓ To connect oil droplets, the **Ag size** and the **distance between droplets** are key parameters

Scientific context

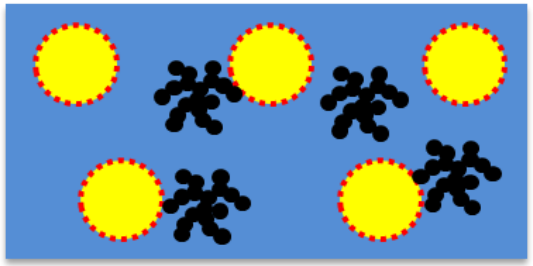
✓ To connect oil droplets, the **Ag size** and the **distance between droplets** are very important.

Ag size

Large aggregates: connection on long distance

Small aggregates: connection on short distance

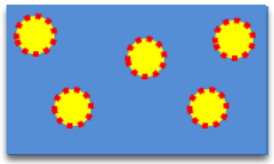
Distance between droplets



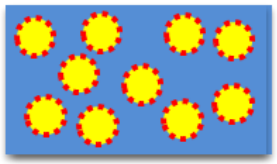
If the distance between droplets is larger than the aggregate size, connections are difficult

✓ Two ways to control the distance between droplets:

- ✓ **Dispersed phase**: droplets are closer with high concentration of anhydrous milk fat (AMF)
- ✓ **Droplet size**: modulated by the homogeneisation pressure. At constant AMF volume fraction, the lower the homogeneisation pressure, the larger the distance between droplets.



High pressure
5% of AMF

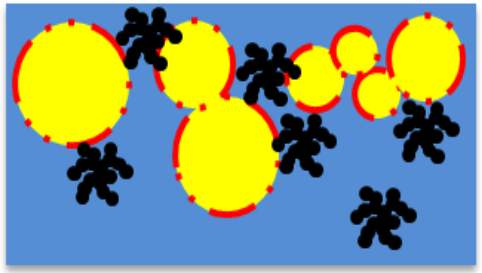


Low pressure
10% of AMF

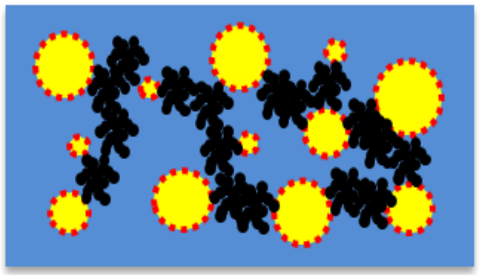
Scientific context

To texture emulsions, a compromise has to be found between:

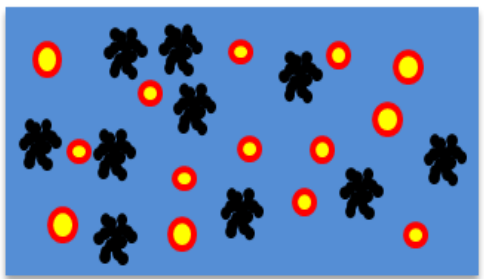
- ✓ The concentration of **NWP**
  - ✓ Enough NWP to stabilize emulsions and control droplet size
  - ✓ Not to much to allow aggregates to connect droplets (interface saturation)
- ✓ The concentration and the size of Ag to connect droplets
- ✓ The droplet size and the volume fraction of AMF to control the distance between them



Not enough NWP



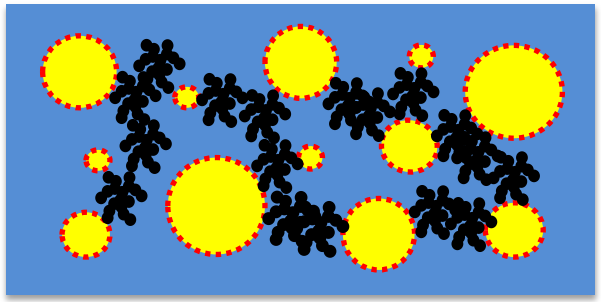
Appropriate amount of NWP



Too much NWP

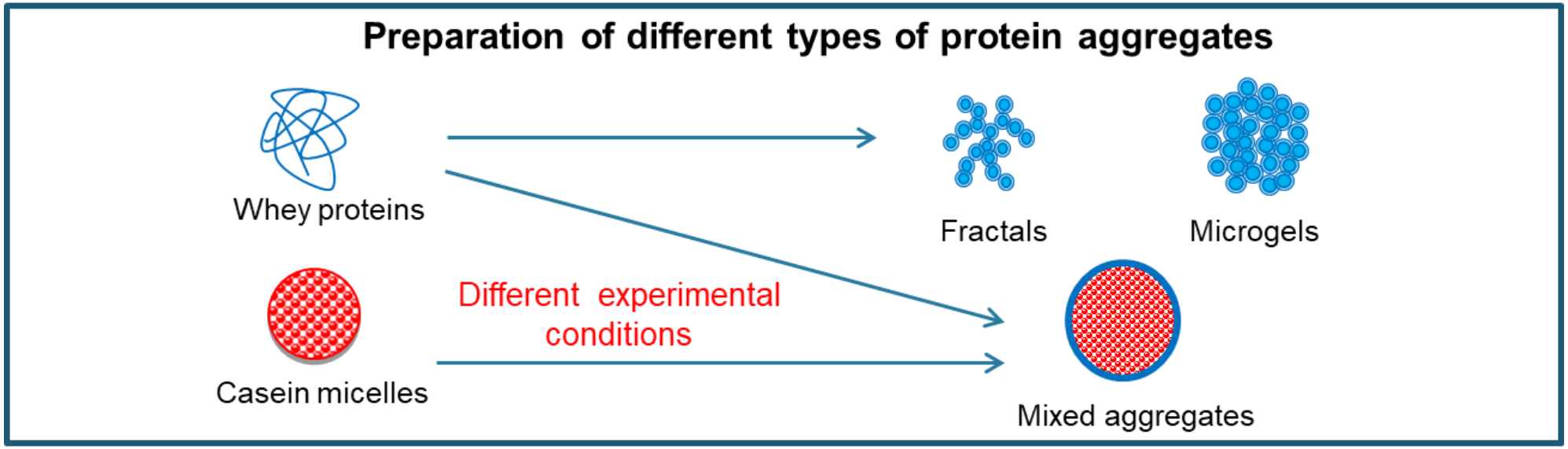
Objectives

- ✓ Use oil droplets to texture emulsion without hydrocolloids
- ✓ Connecting oil droplets with whey protein aggregates (Ag)



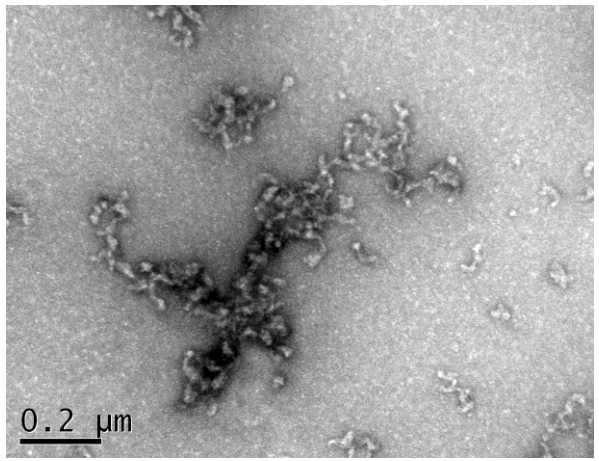
Aims of the study	Replace food additives like thickening or gelling agents in neutral dairy products or improve the texture of acid dairy products
	Texturize even low fat content products

What kind of aggregates ?

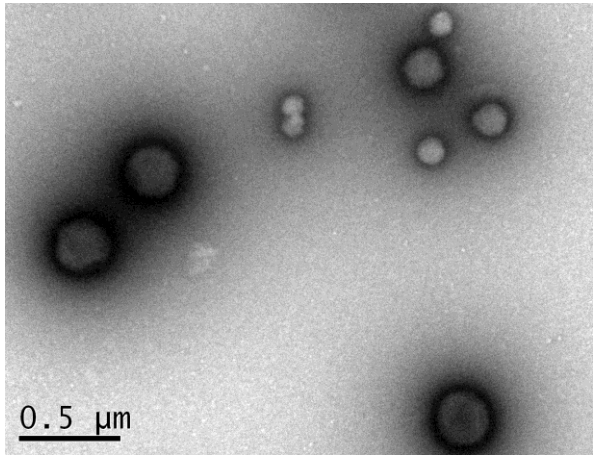


What kind of aggregates ?

Fractals



Heating conditions



Microgels

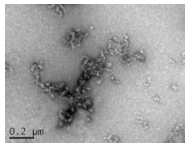
- Whey protein solution at 50 g/l
- **pH 7**
- **[NaCl] : 0 to 45 mM**
- 80°C - 2h

Branched structures,
[NaCl]-dependent size dispersion
70 to 300 nm

- Whey protein solution at 50 g/l
- **pH 5,8**
- 85°C - 1h

Compact spherical structures,
monodisperse size
200 nm

Neutral emulsion fabrication



80mM NaCl

Heating at 60° C

Mixing

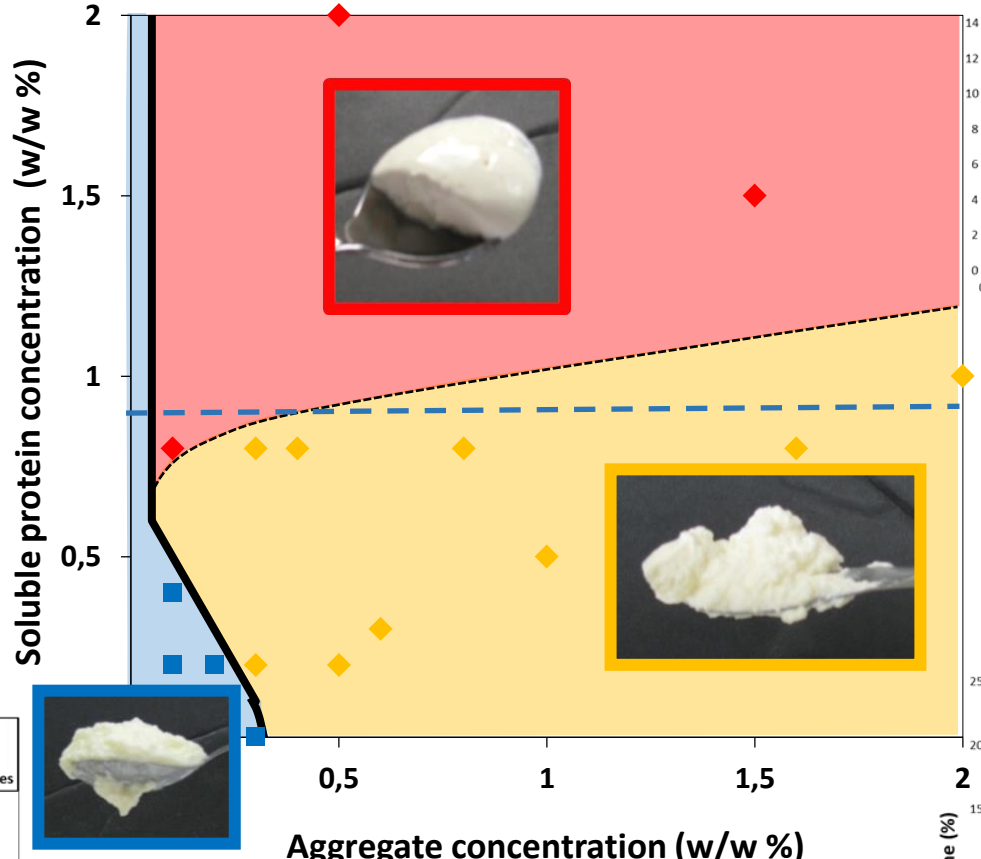
Pre-emulsification ultraturax (14000 rpm; 3 min)

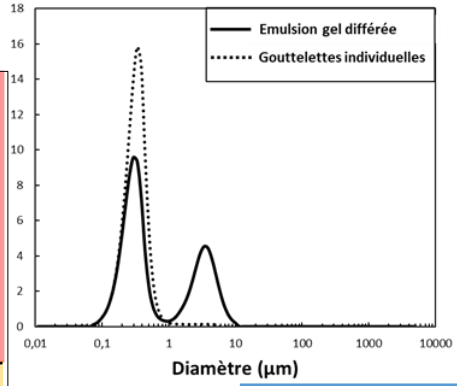
5 min; different pressions

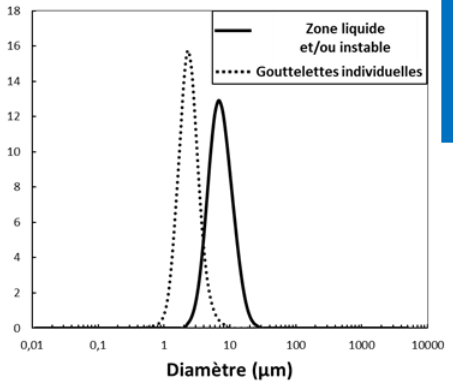
Stockage at 60, 20 et 4° C

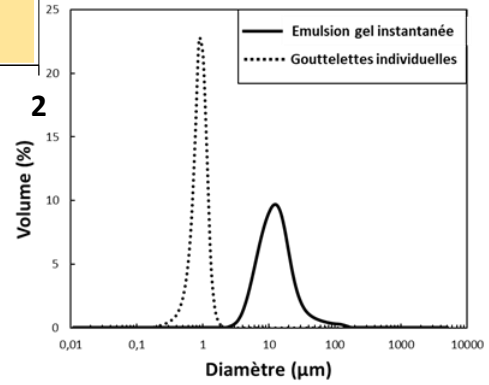
- *Granulometry*
- *Microscopy*
- *Visual observations*
- *Rheology*

State diagrams obtained with fractal aggregates (30 / 500)







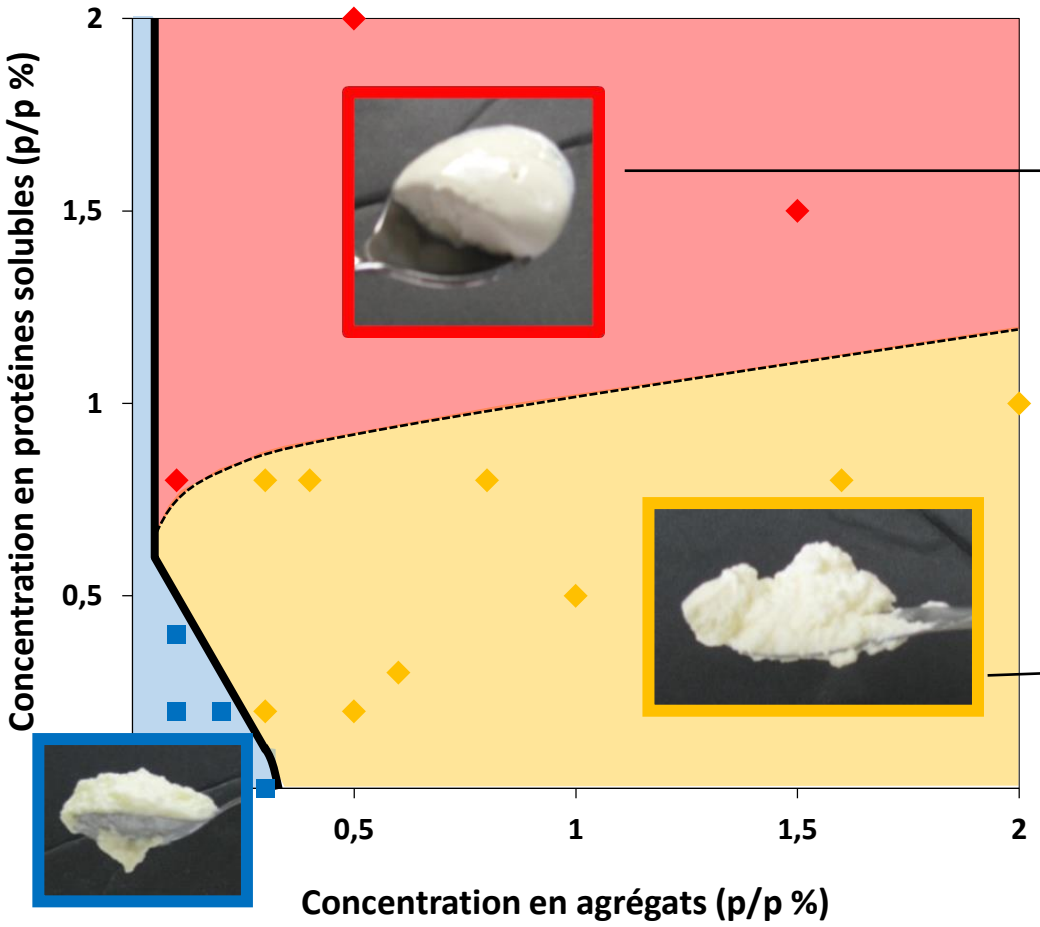


AMF(%)	Pression (bars)
5	100
30	**500**

Regions

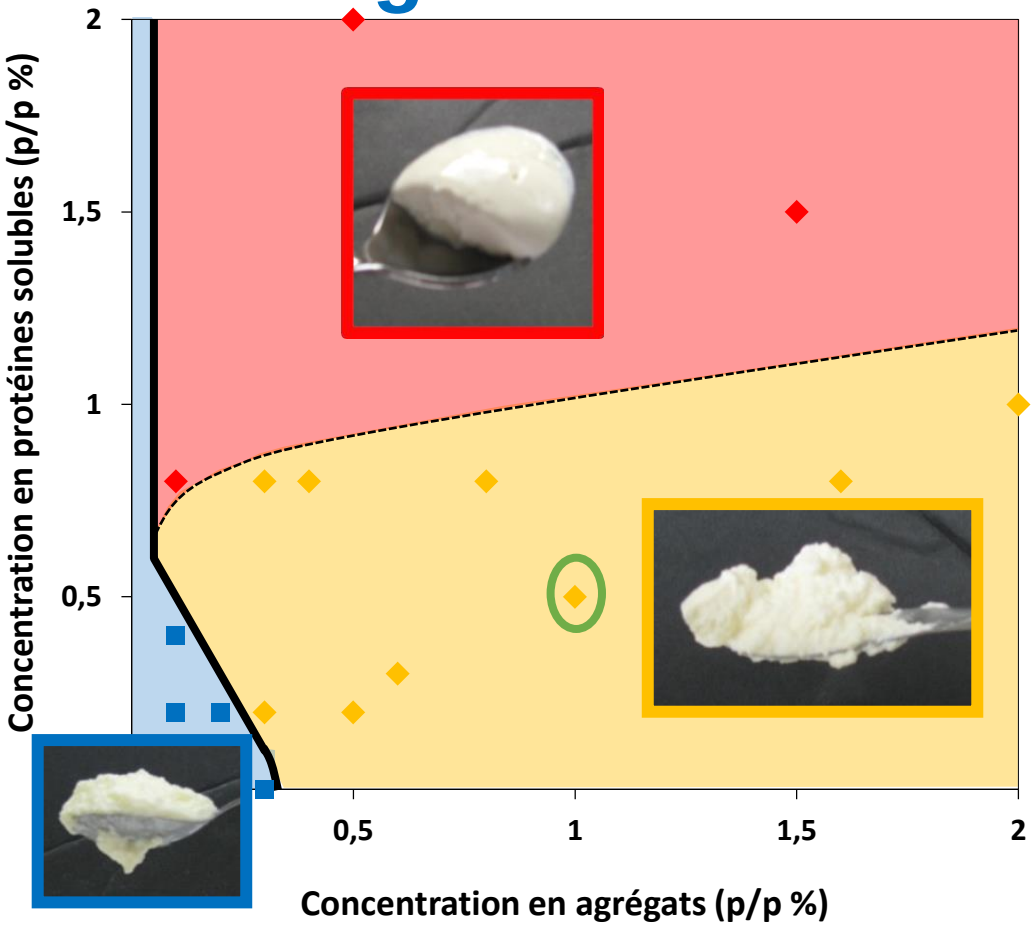
- Liquid or instable
- Instant gel
- **Delayed gel**

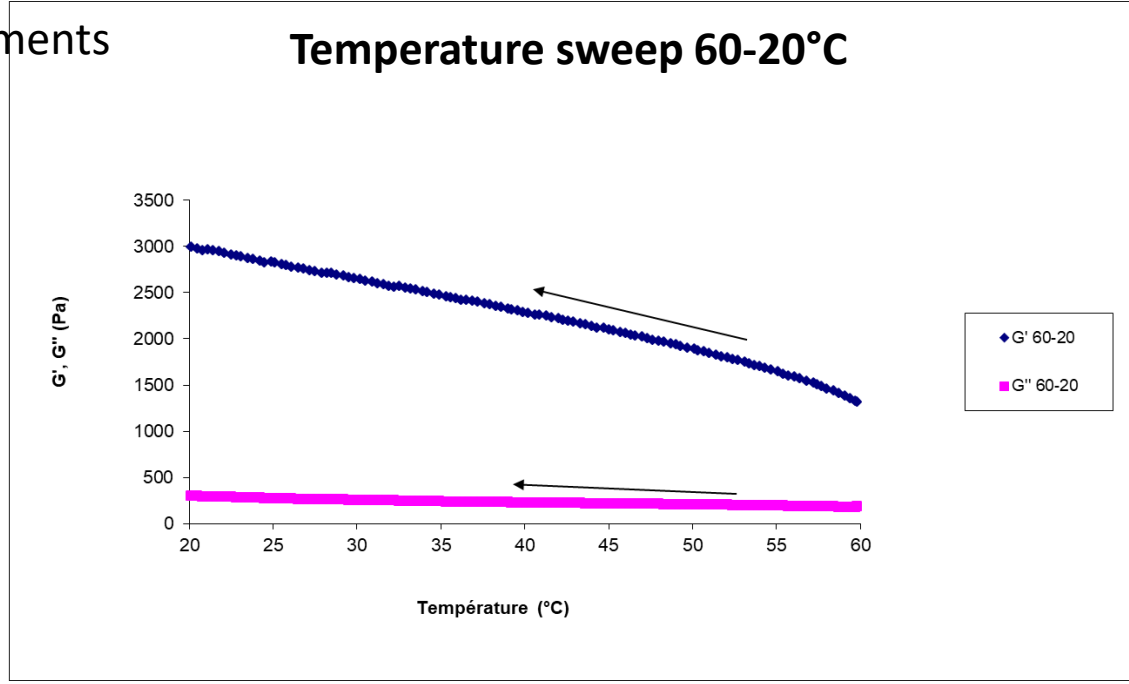
State diagrams obtained with fractal aggregates (30 / 500)

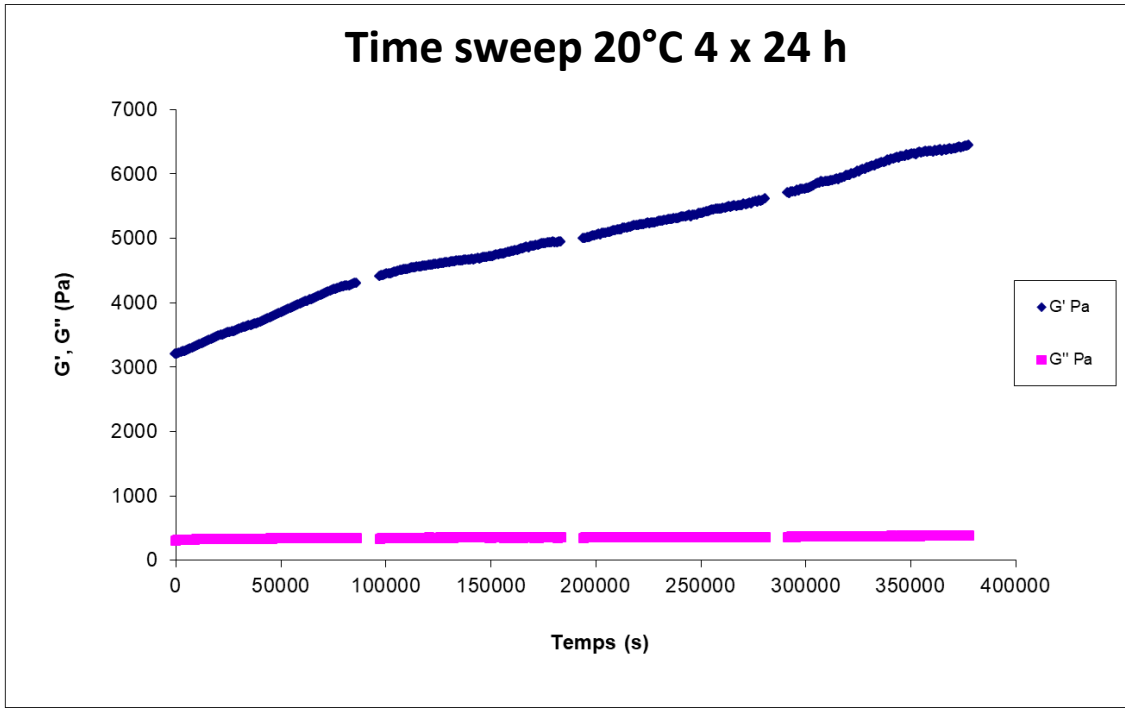


Rheological behaviour

AR2000, TA Instruments
Plate-plate 40 mm
Gap 1 mm
γ 0,5%, 1 rad/s







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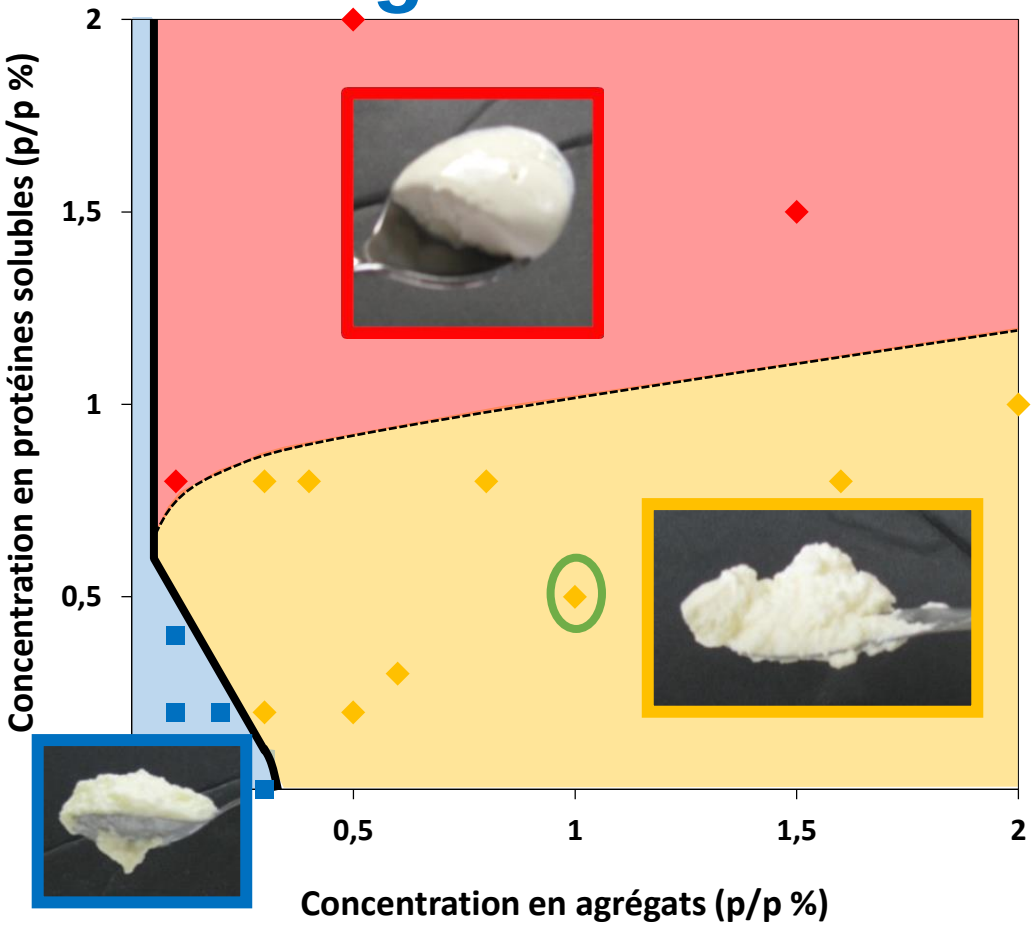
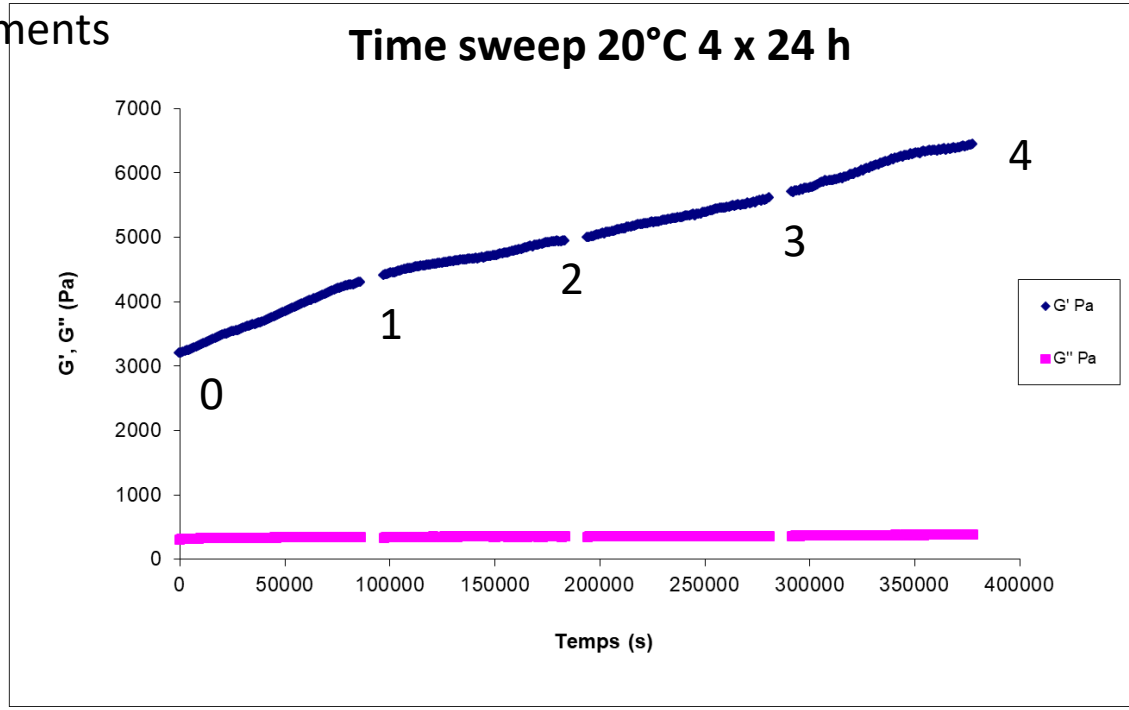
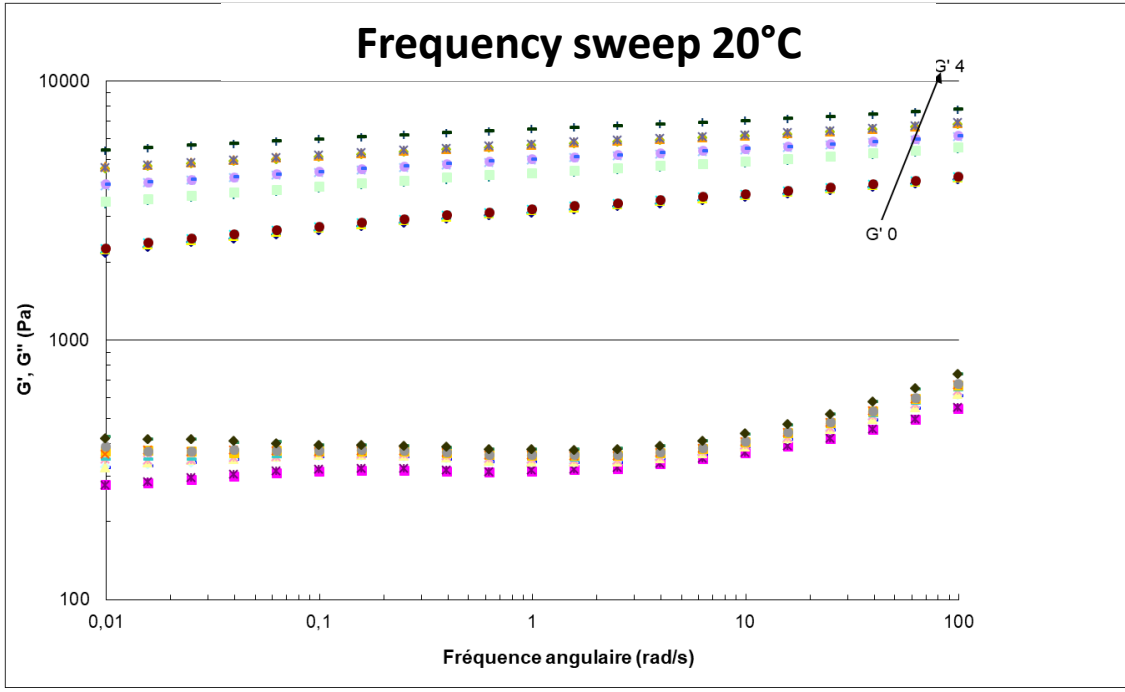
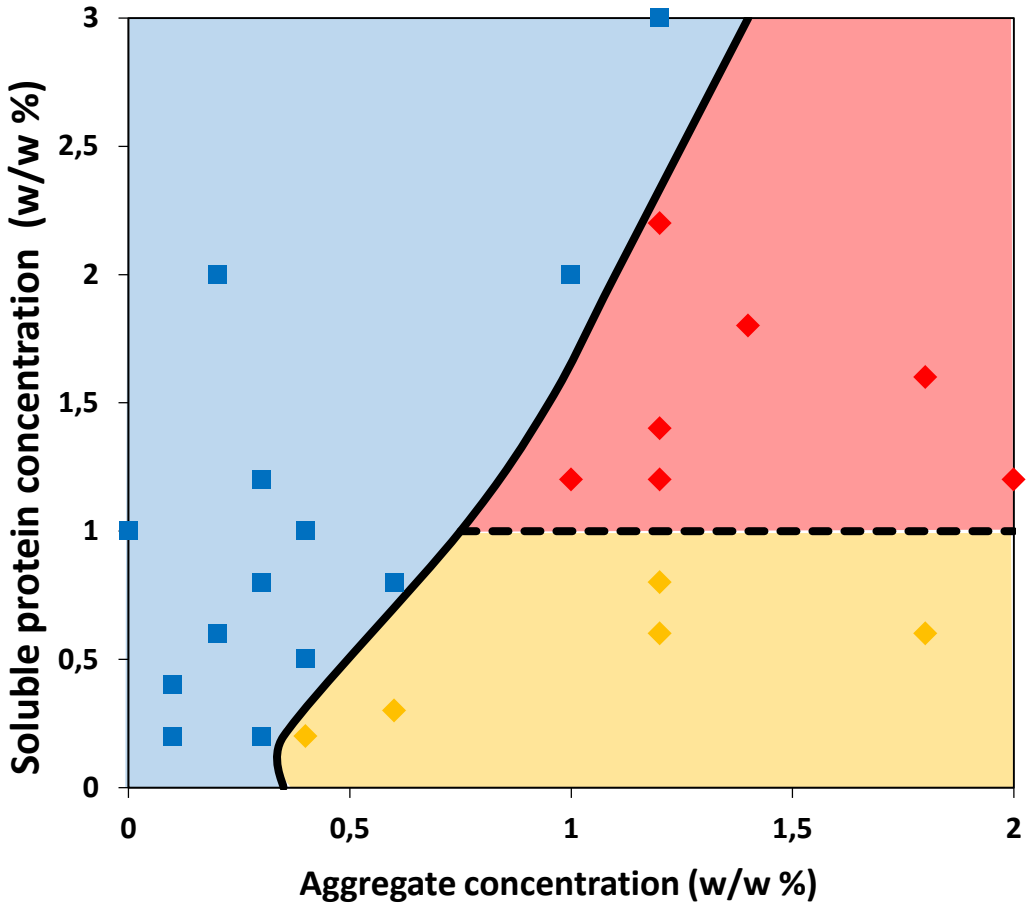






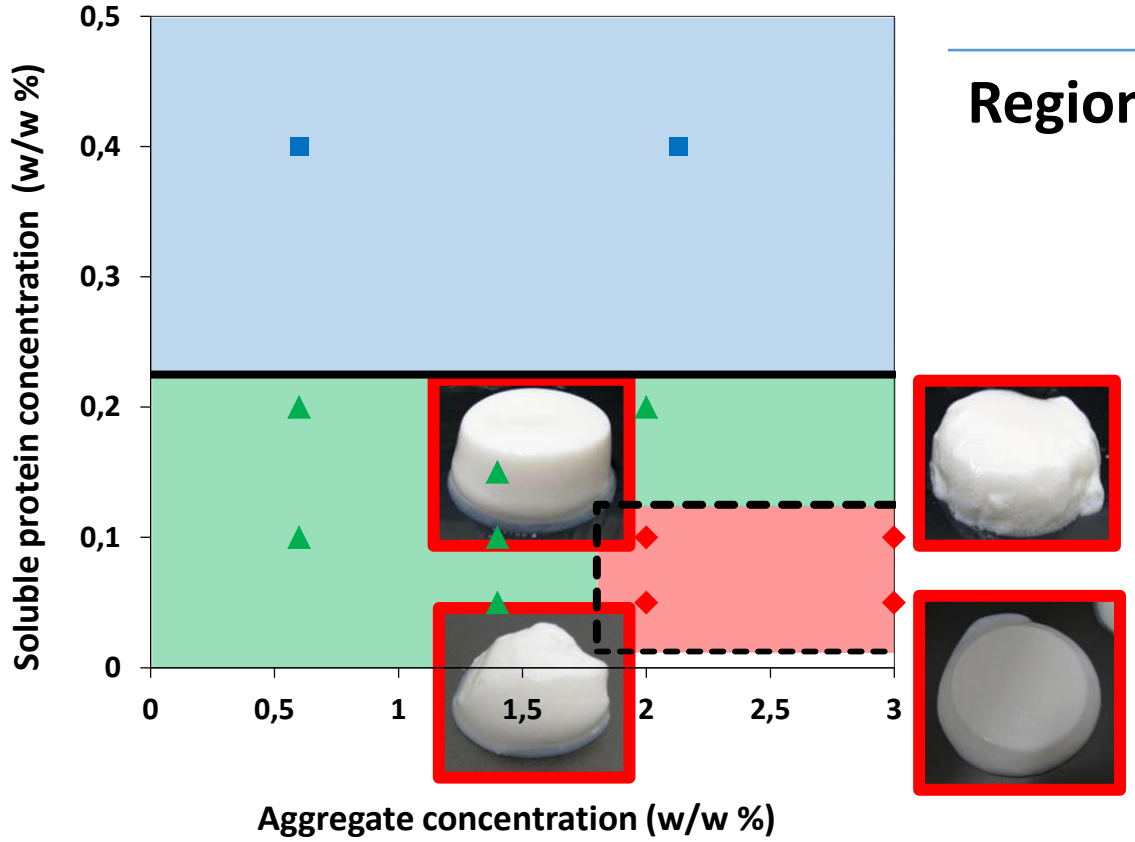
State diagrams obtained with fractal aggregates (30 / 100)



AMF (%)	Pression (bars)
5	**100**
30	500

Regions	
	Liquid or instable
	Instant gel
	Delayed gel

State diagrams obtained with fractal aggregates (5 / 500)



Regions

- Liquid or instable
- Heterogeneous
- Delayed gel
- ~~Instant gel~~

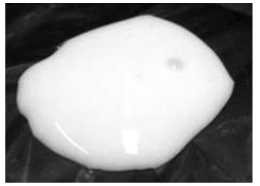
MGLA (%)	Pression (bars)
5	~~100~~
30	500

Gels are able to reform after shearing

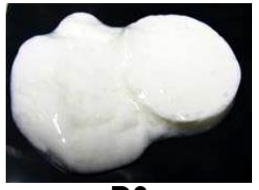

D7 (without breaking)

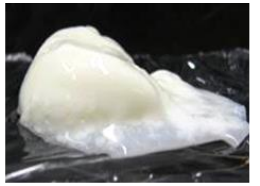
If [Ag] increases➔ liquid emulsion

Soluble proteins in aggregates

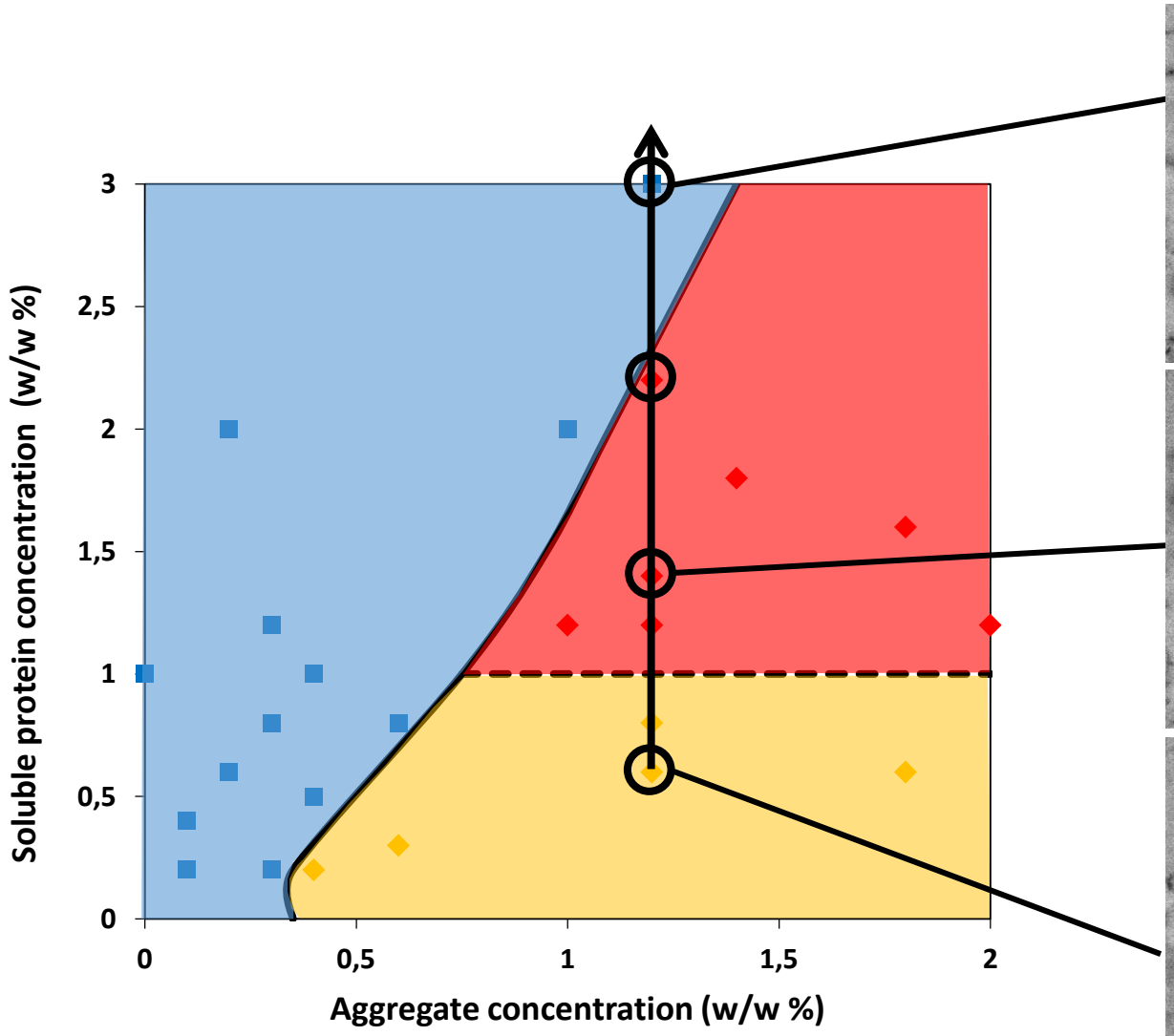

After breaking

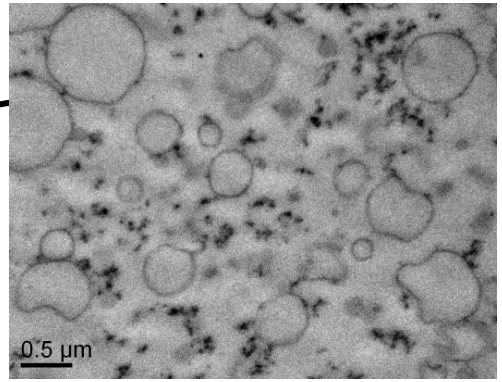

D1

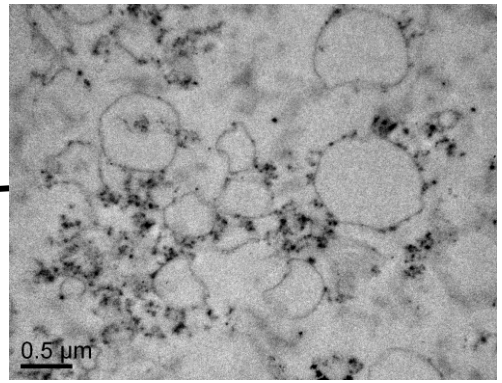

D3

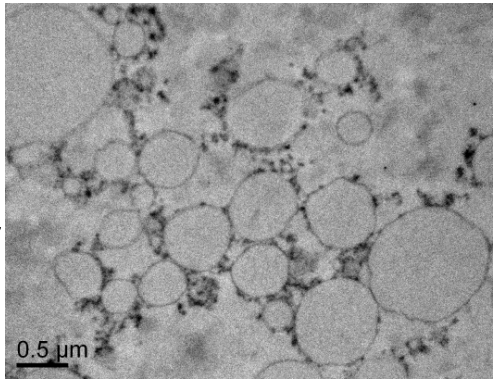

D7

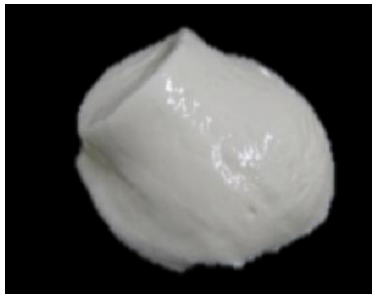
Interface connectivity





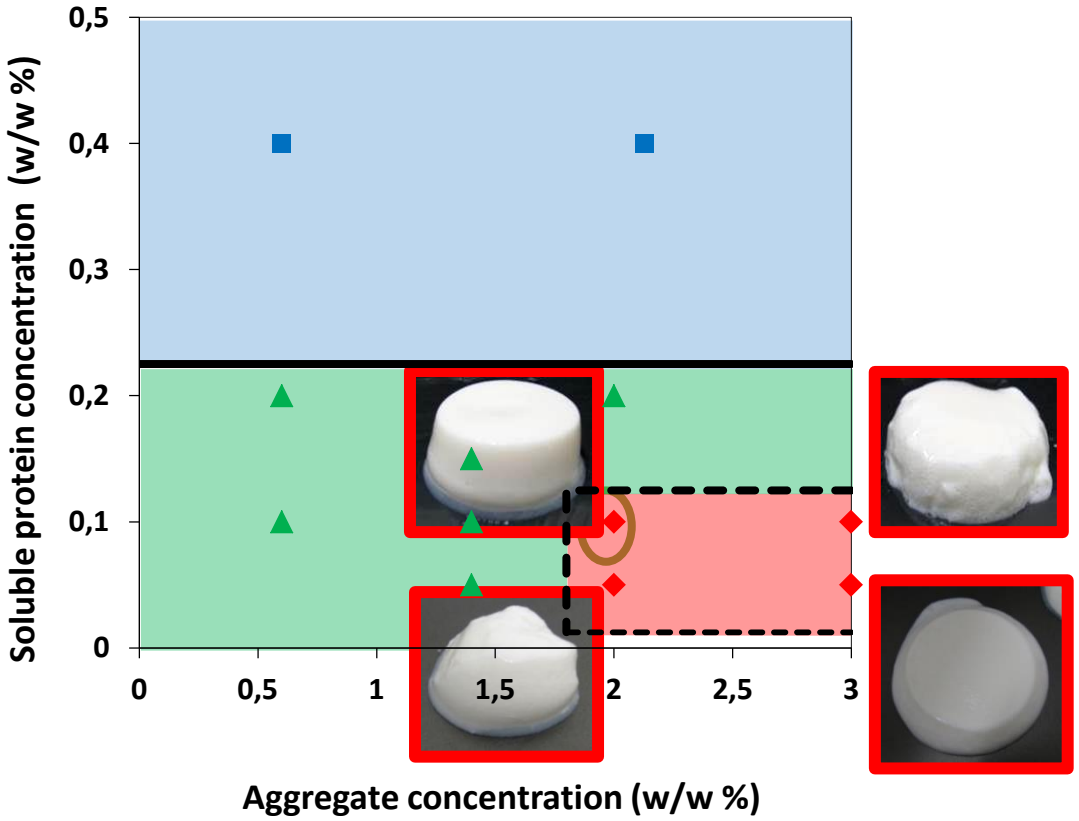




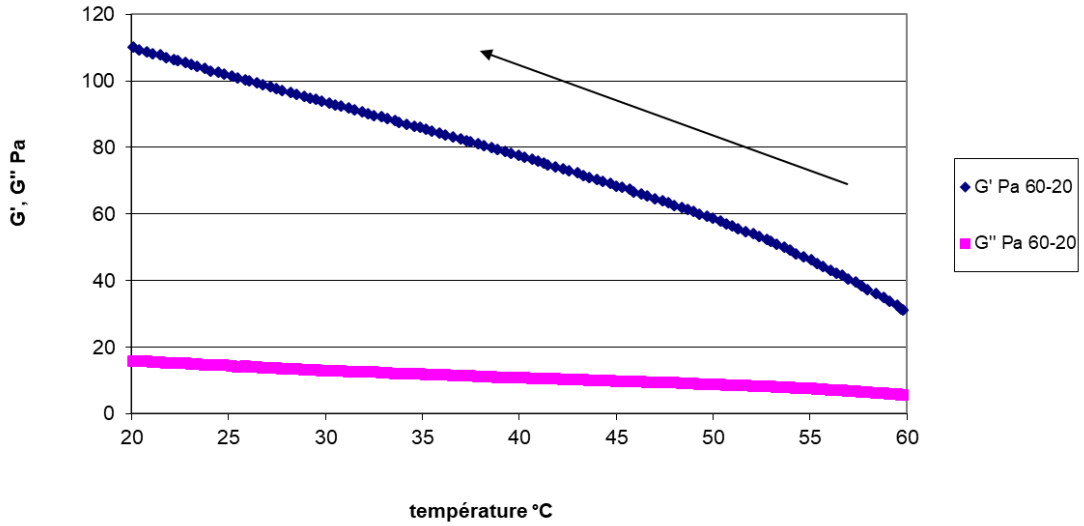


Rheological behaviour

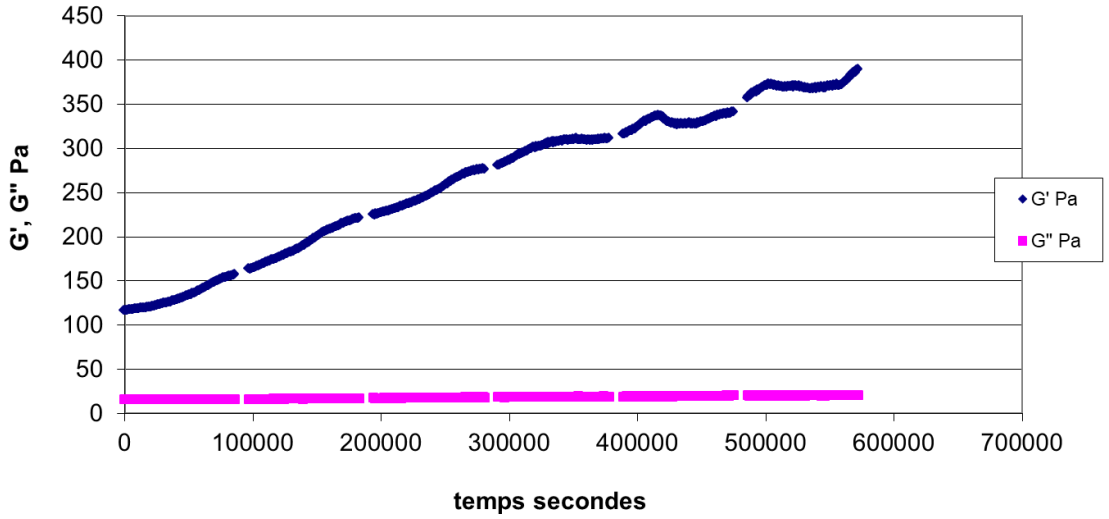
AR2000, TA Instruments
Plate-plate 40 mm
Gap 1 mm
γ 0,5%, 1 rad/s



Temperature sweep 60-20°C

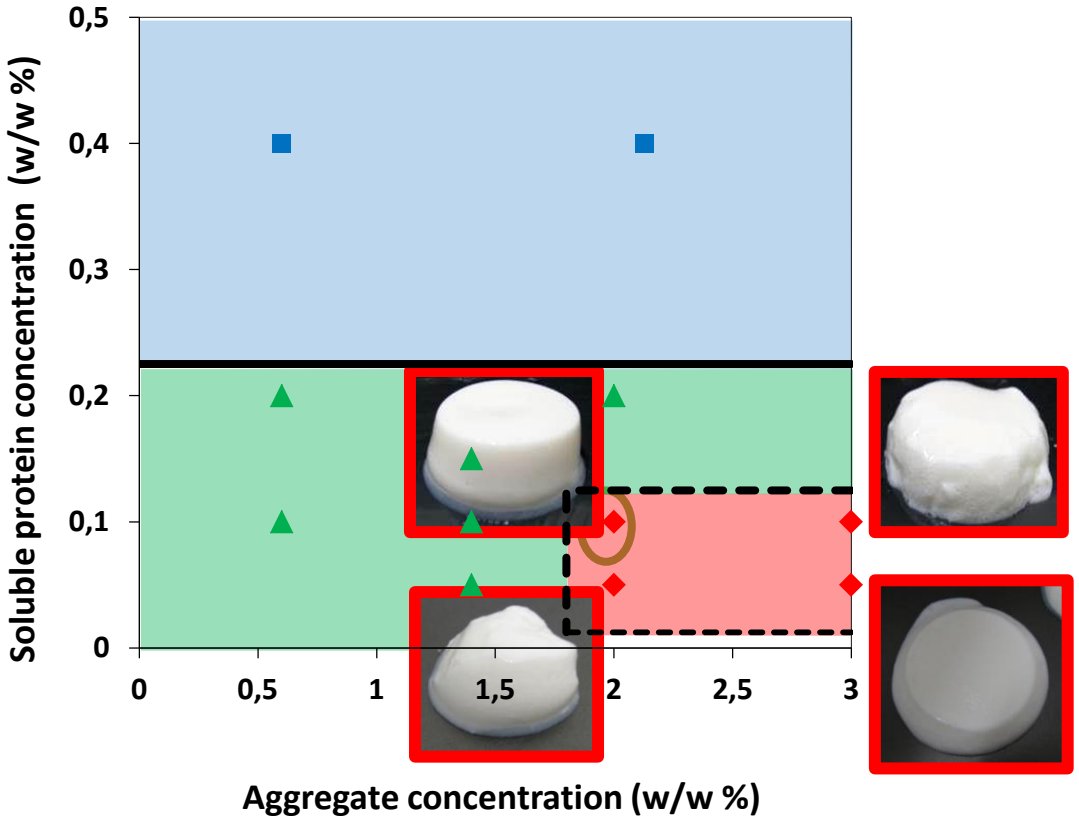


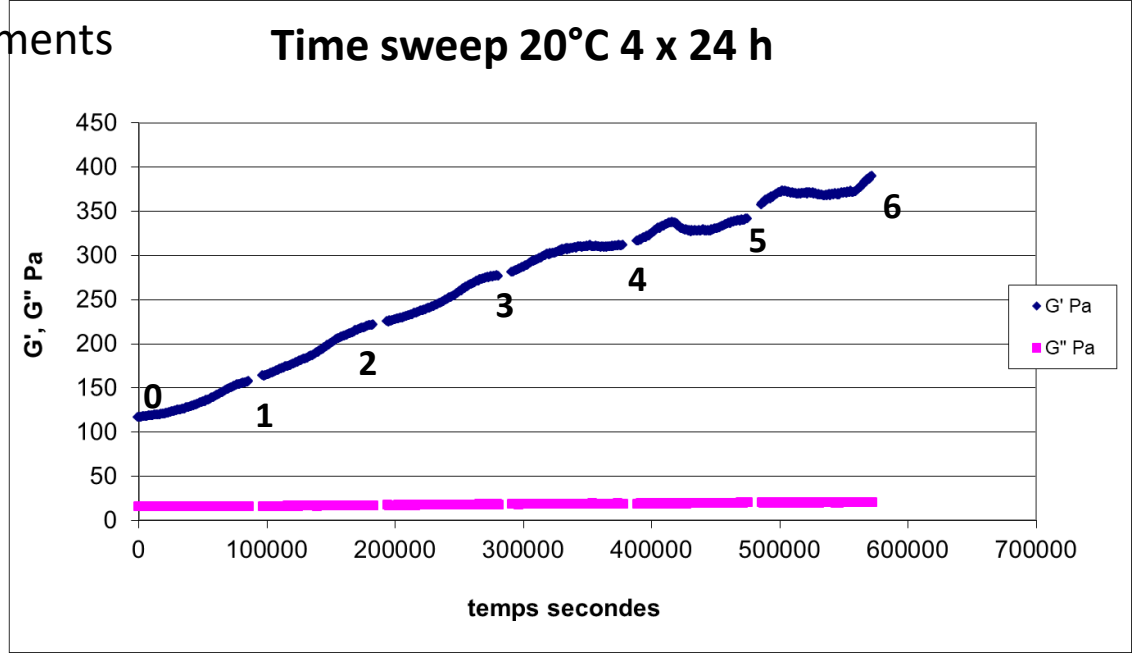
Time sweep 20°C 6 x 24 h

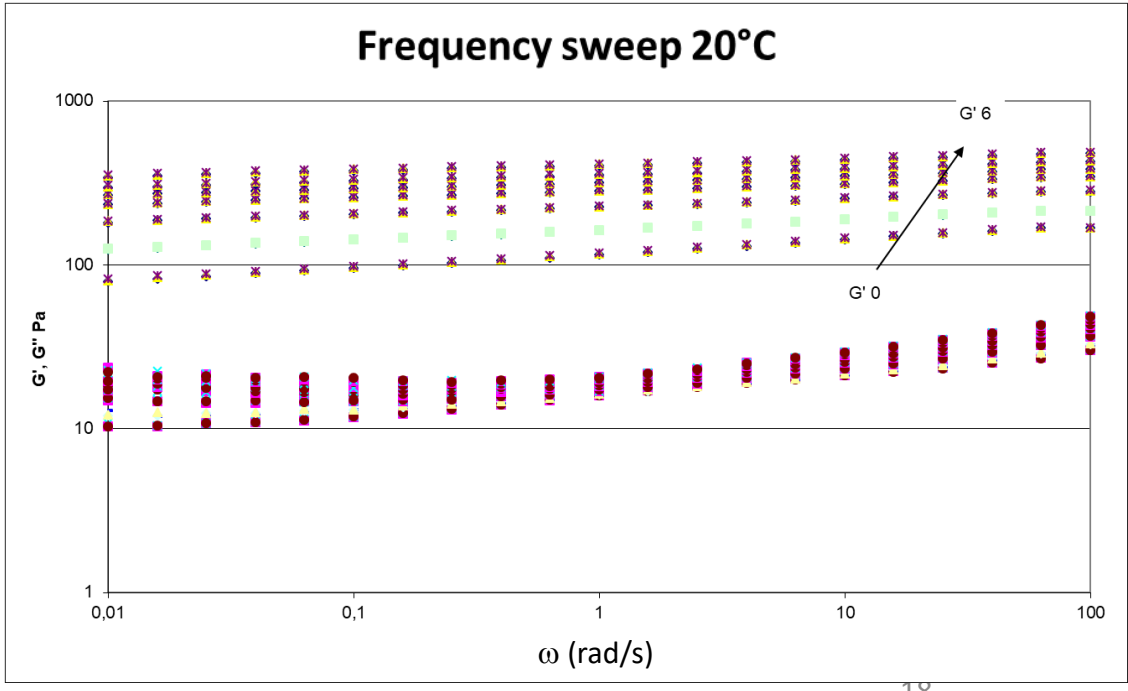


Rheological behaviour

AR2000, TA Instruments
Plate-plate 40 mm
Gap 1 mm
γ 0,5%, 1 rad/s



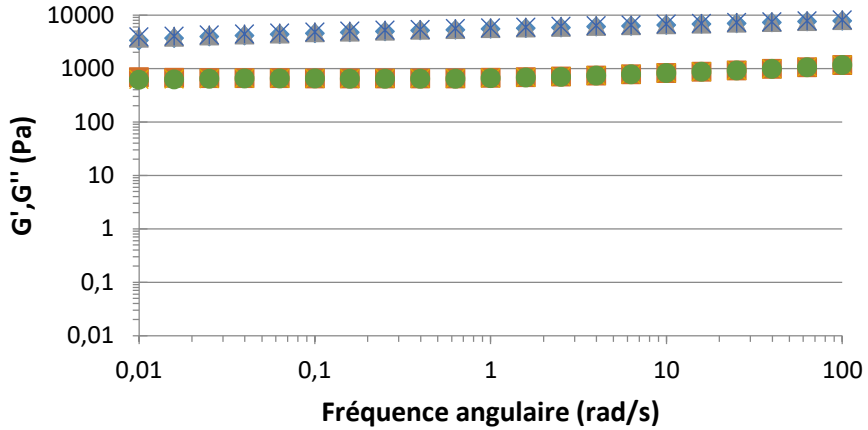




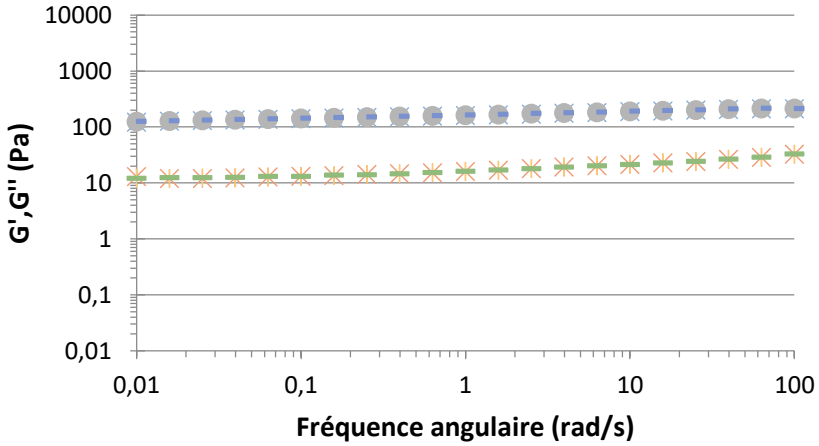
Rheological behaviour

AR2000, TA Instruments
Plate-plate 40 mm
Gap 1 mm
γ 0,5%, 1 rad/s

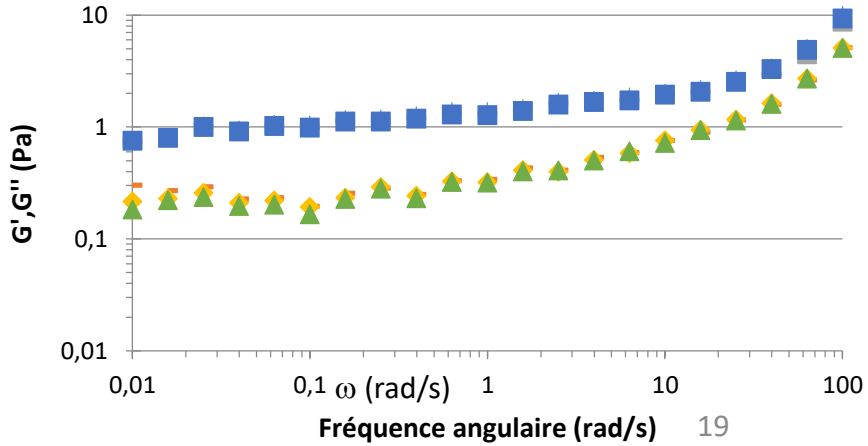
AMF 30%; NP 0,5% ; Ag 1%



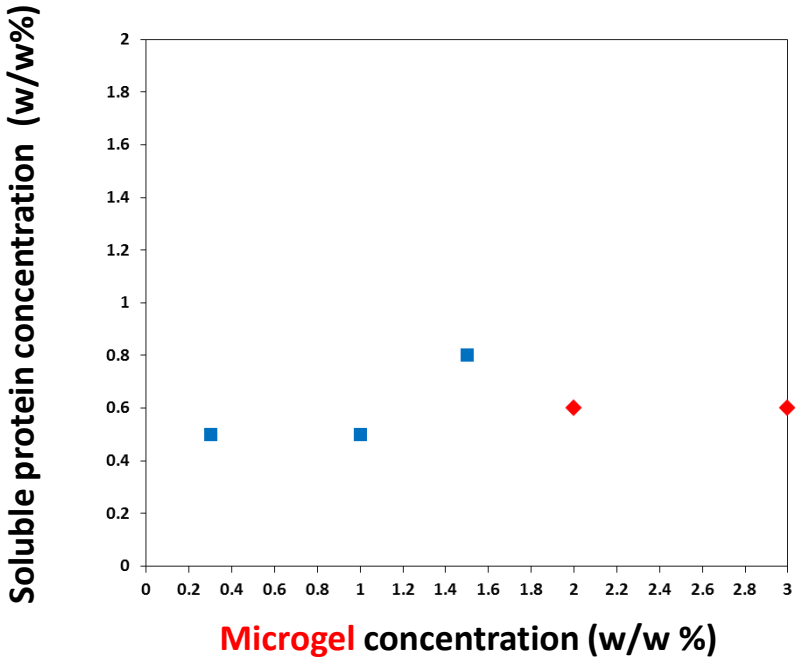
AMF 5%; NP 0,1 %; Ag 2%

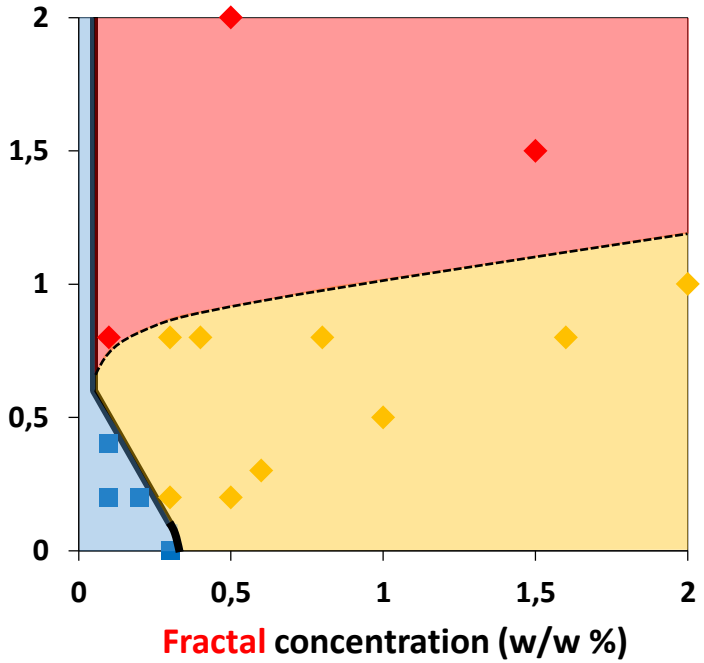


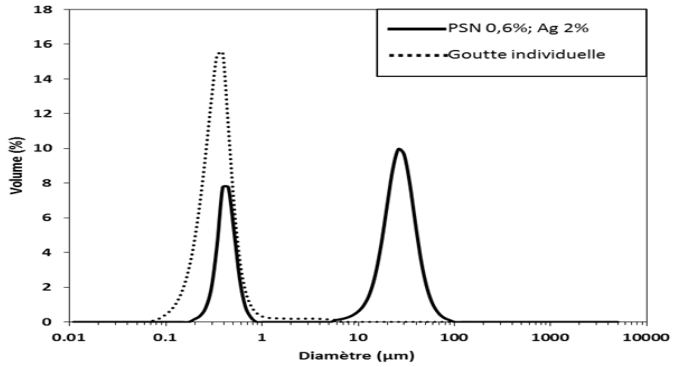
AMF 5%; NP 0,1% ; Ag 3%

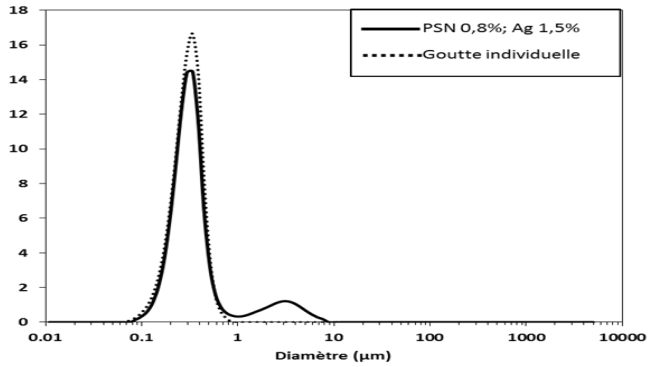


State diagrams obtained with microgels (30 / 500)





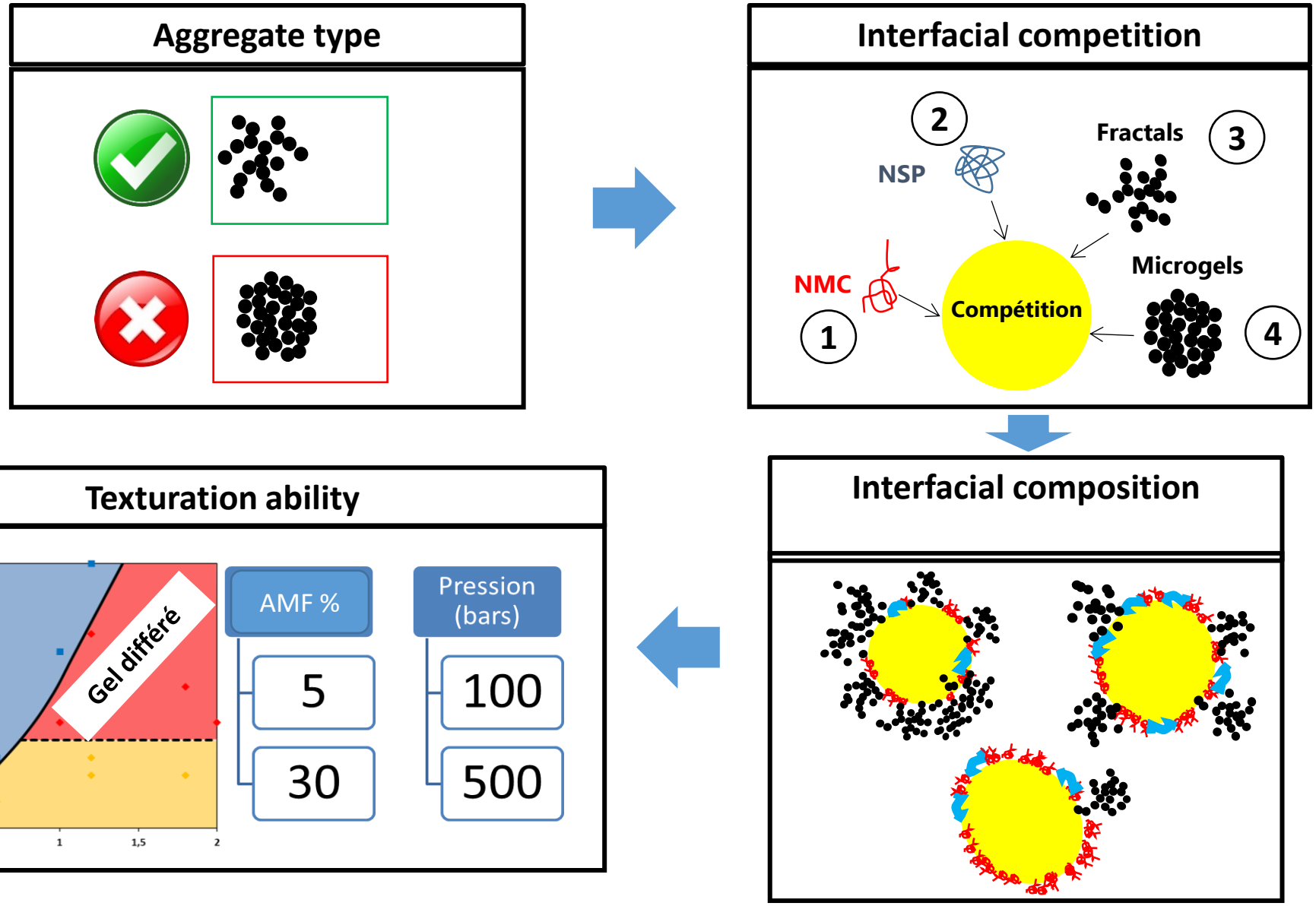




Few microgels

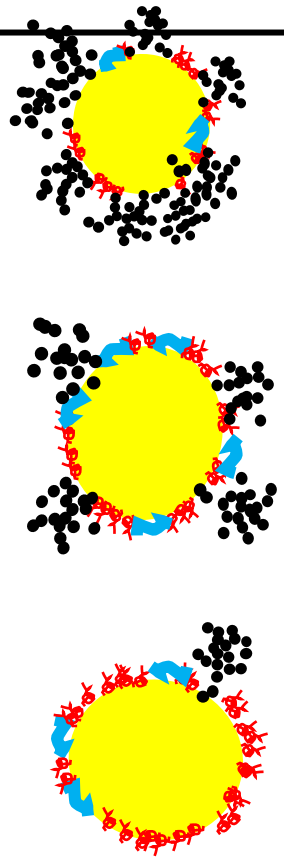
➔ **Low affinity for the interface**
➔ **Less efficient to connect droplets**

For neutral emulsions



For neutral emulsions

Interfacial composition



Texture control

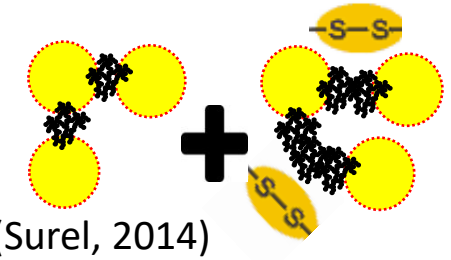
Instant

Delayed

Liquid

Molecular interactions

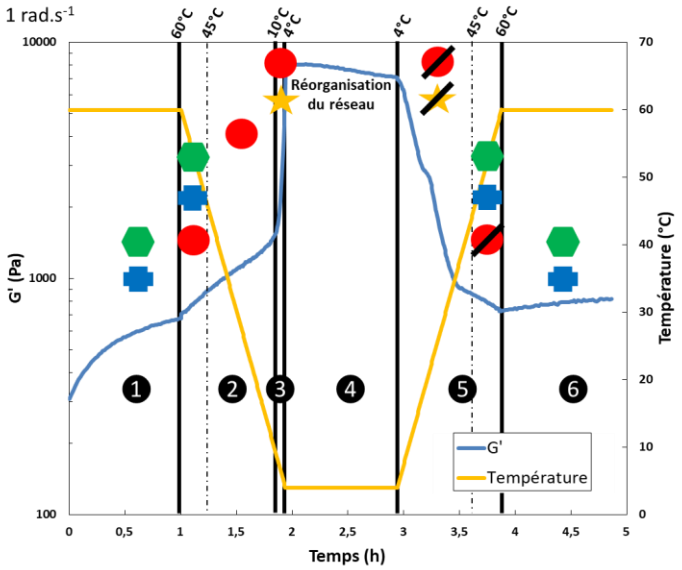
Pendant l'homogénéisation

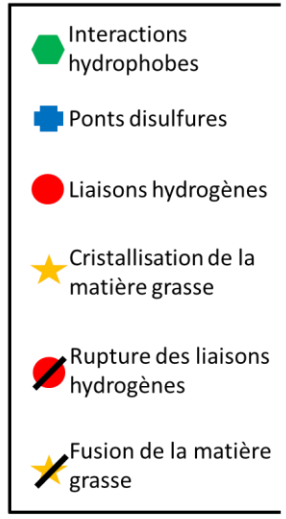


(Surel, 2014)

Pendant le stockage

- ✓ Disulfure bonds
- ✓ Hydrogen bonds
- ✓ Hydrophobic interactions
- ✓ Fat Cristallisation

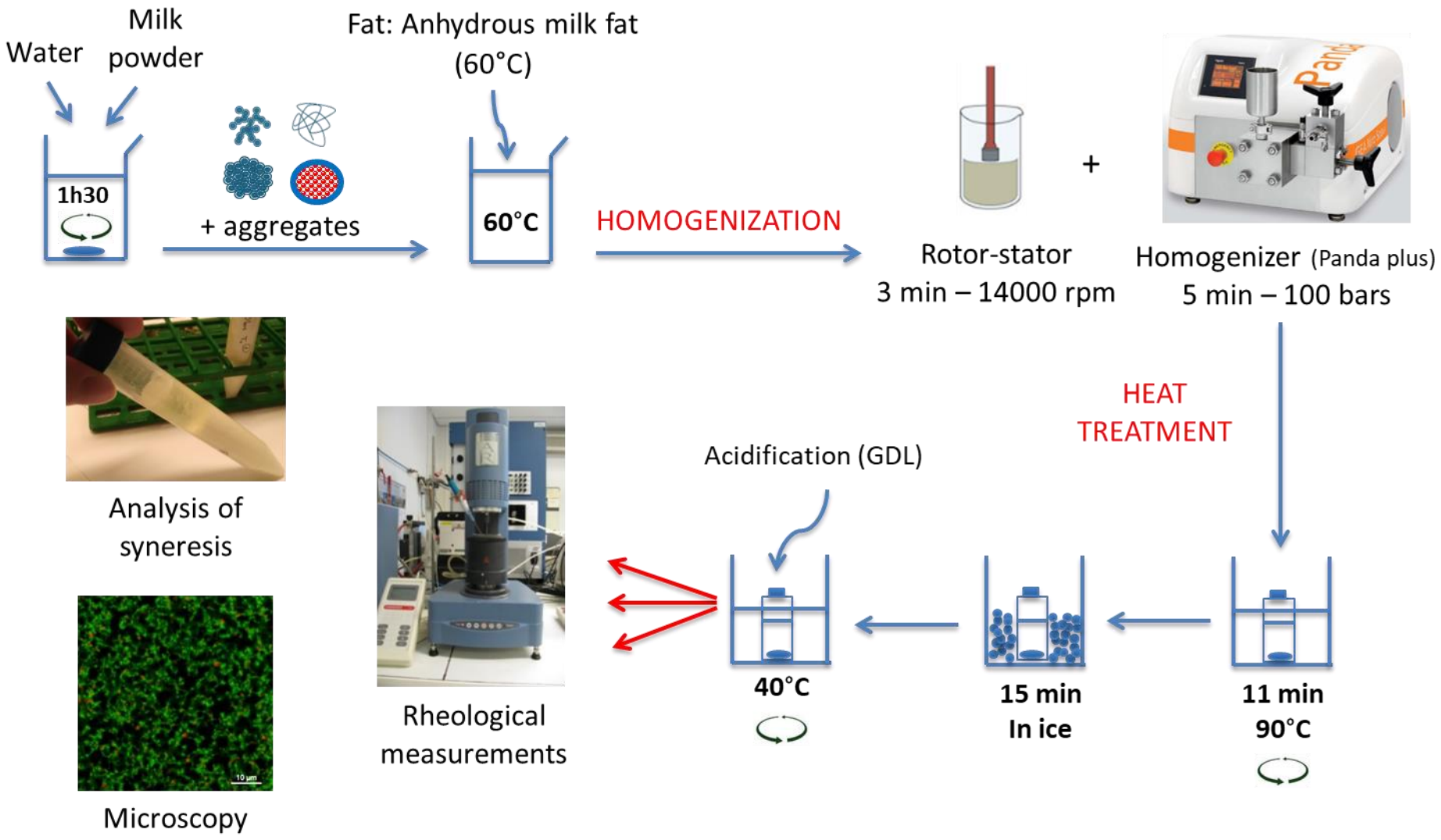




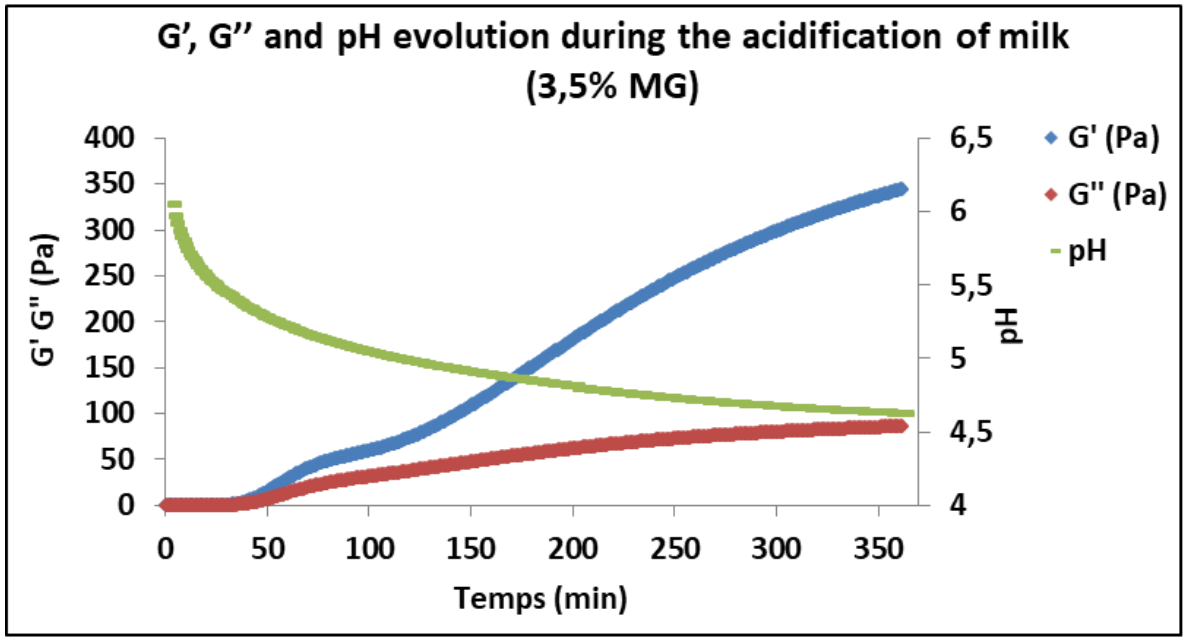
30% AMF Emulsion ; 100 bars

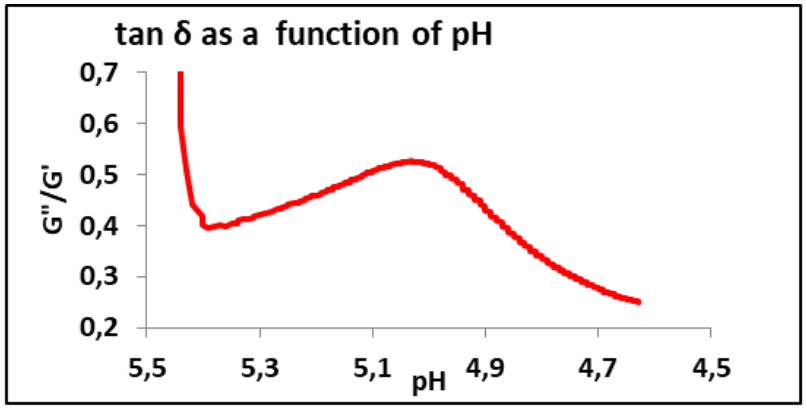
Protein-protein interactions are predominant

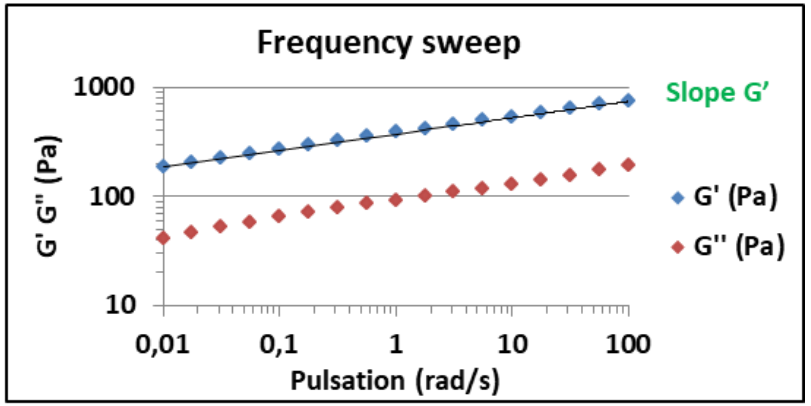
Acidified dairy system



Rheological behaviour of acidified dairy systems



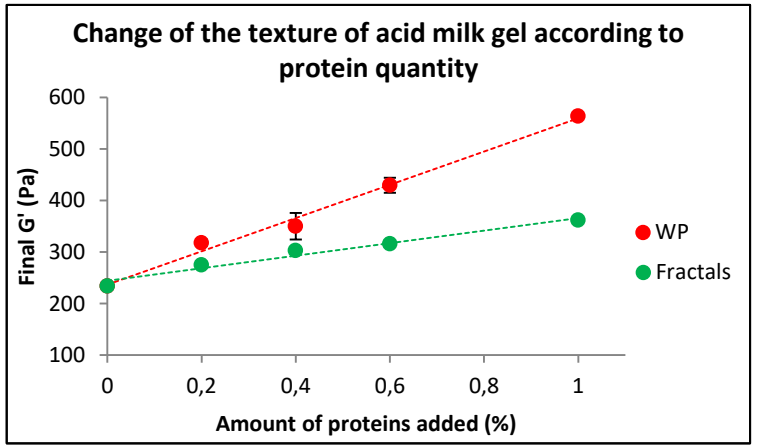


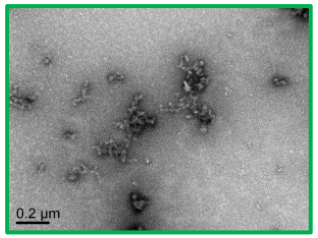


Sample	Gelation time time	Gelation pH	G' max (1 rad/s)	Slope G' (FS)
No fat	29 min	5,44	234	0,164
3,5% AMF (100 bars)	29,4 min	5,45	340	0,150

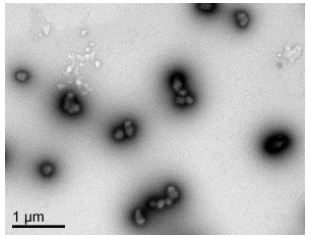
Acid milk gel without fat

Better structuring and firmness with **increasing concentration**
Decrease of syneresis



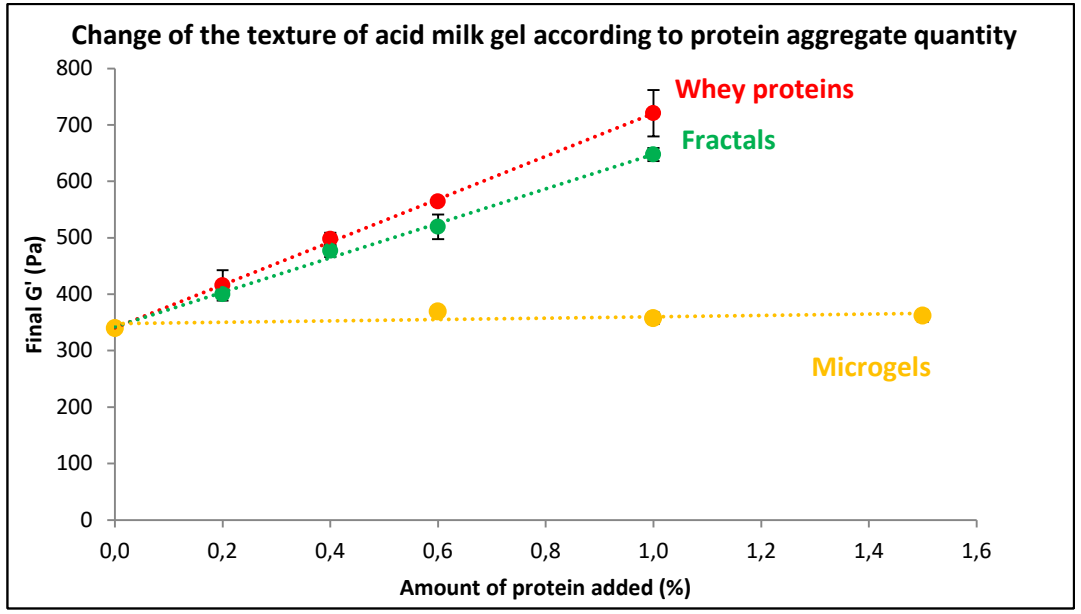


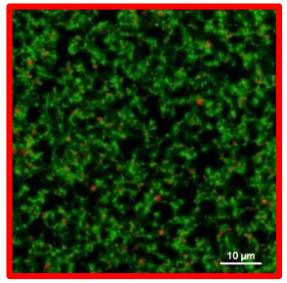
Good structuring and firmness
Decrease of syneresis
Less efficient than WP



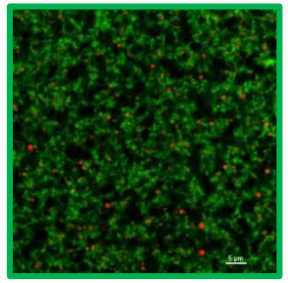
No improvement of firmness and no decrease of syneresis
→ Protein enrichment of products

Acid milk gels with 3.5% fat and aggregates

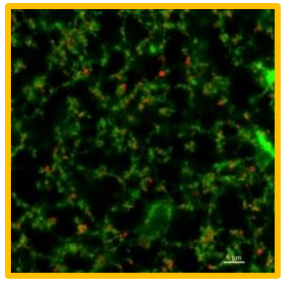




1% WP



1% fractals

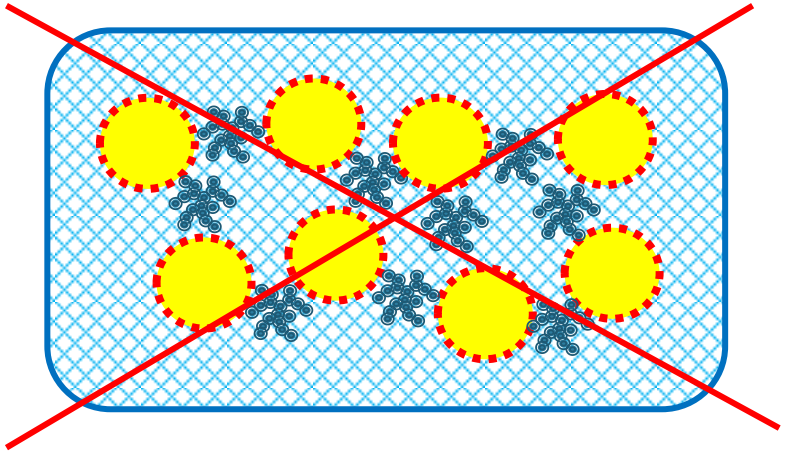


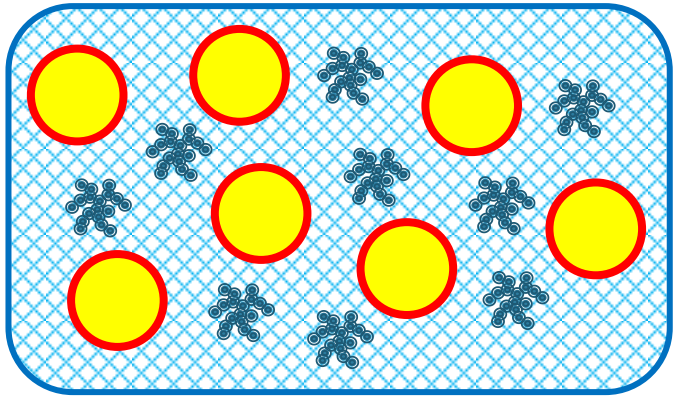
1% microgel aggregates

- WP and Fractals: **Increase of the gel strength** (slightly weaker with fractals)
  - **Similar aspect of protein network**
  - Same evolution with or without fat and WP/fractals → **impact on the interface?**
- Microgels: **constant** final G‘, no modification with increasing concentration → **connection with the network?**

Modulation of texture

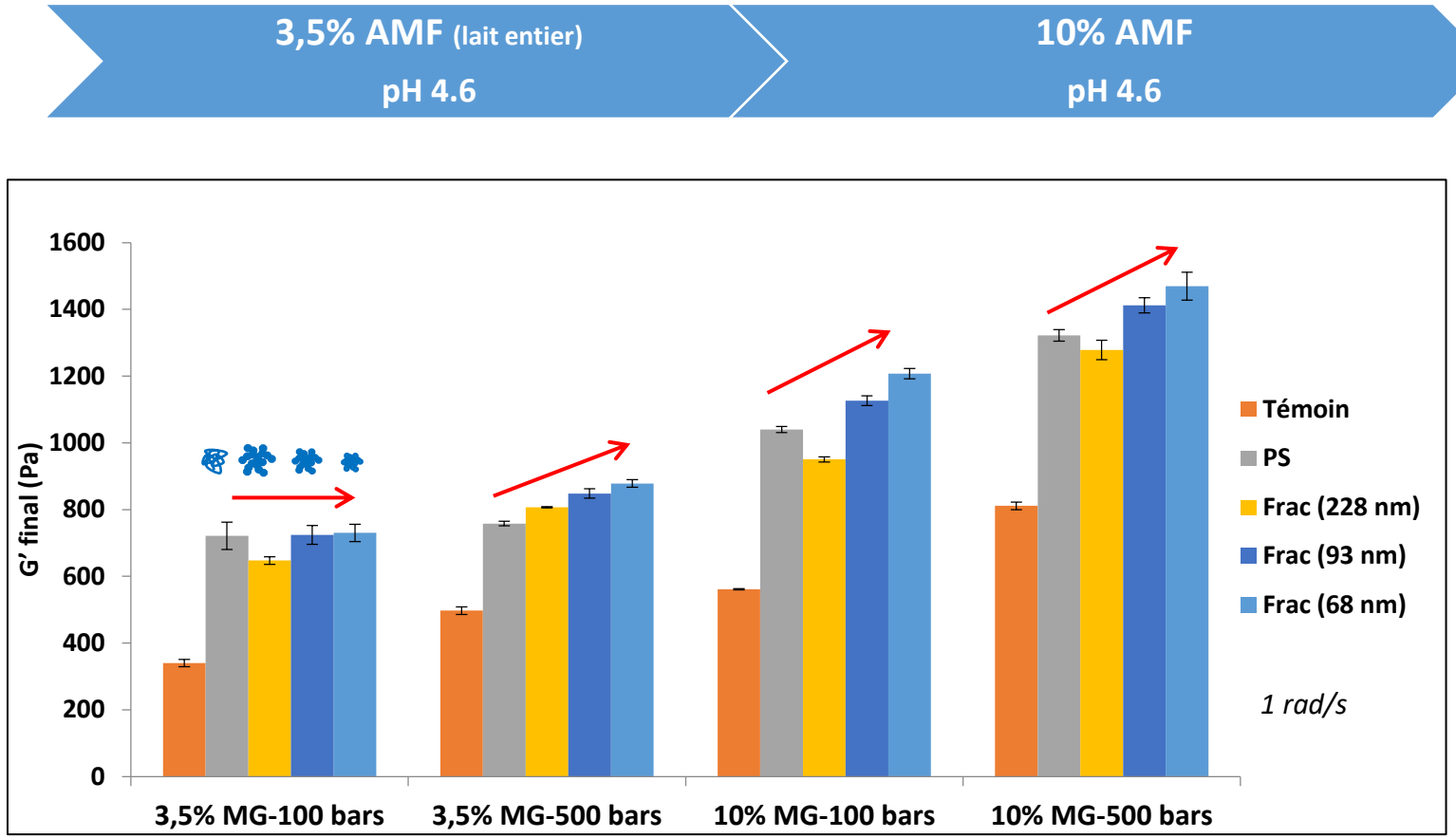
At 3,5% fat : **interface totally occupied by caseins**
aggregates play a rôle only in the continuous phase





Effect of interfacial surface and of fractal aggregate size

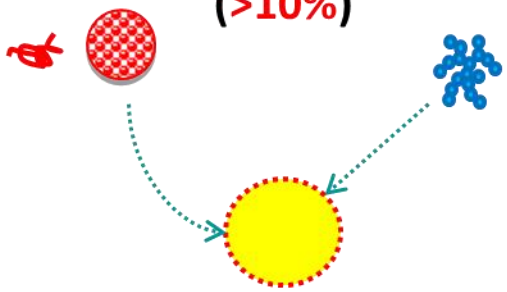
- Strong effect on interfacial surface increase on gel texture
- Weaker competition for interface when interfacial surface increases
- Stronger gels obtained when fractal aggregate size is lower



Final G' (pH 4.6) as a function of fractal aggregate size at a fixed concentration of 1% (w/w)

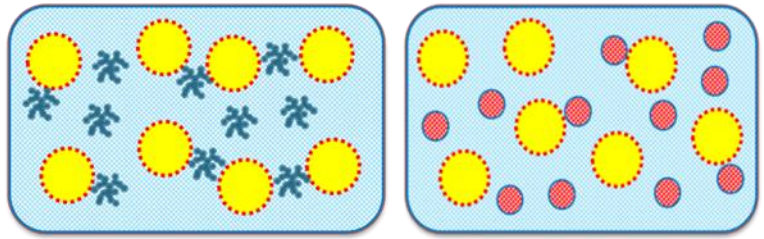
For acidified systems

Aggregates at the interface only in systems with high AMF content (>10%)



Caseins : limiting amount

Possible to control texture (via connexion at interface)



Different rôle depending on the aggregate structure

Fractals
Strengthening of the network

Microgels and mixed
No effect

Merci pour votre attention

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Région BRETAGNE

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