



HAL
open science

Soft matter approaches for food proteins: interfacial and foaming properties

Stéphane Pezennec, Valérie Lechevalier-Datin

► **To cite this version:**

Stéphane Pezennec, Valérie Lechevalier-Datin. Soft matter approaches for food proteins: interfacial and foaming properties. STLOpen Days 2019, Mar 2019, Rennes, France. hal-02097222

HAL Id: hal-02097222

<https://hal.science/hal-02097222>

Submitted on 4 Jun 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

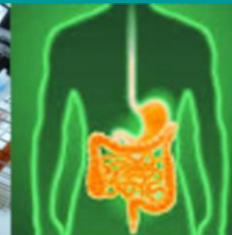
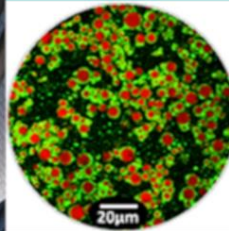
AGRO
CAMPUS
OUEST



Soft matter approaches for food proteins: interfacial and foaming properties



STLOpen Days
19-21 March 2019



Valérie Lechevalier & Stéphane Pezenec



Protein functionality

- relation of technological aptitudes to intrinsic features
- 'biochemical' viewpoint
(amino-acid composition, sequence, structure...)
- *colloidal* viewpoint
(size, charge, anisotropy, pressure, transport, concentration...)
- the two worlds meet at interfaces

Boire et al., 2019 ([doi:10/c3jt](https://doi.org/10.1016/j.c3jt))

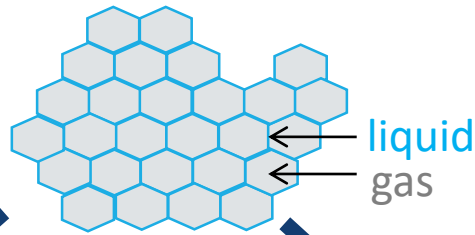
Interfacial properties of proteins

- proteins as surfactants: adsorption to hydrophobic interfaces
- irreversible adsorption
- unwanted consequences
(loss of enzymatic activity, fouling...)
- target effects: stabilization of dispersed systems
- our focus: air—water interface, foams

Outline

- approach & tools
- proteins at the air—water interface
- (interfacial) crowding
- properties of protein foams

Liquid foams are unstable systems



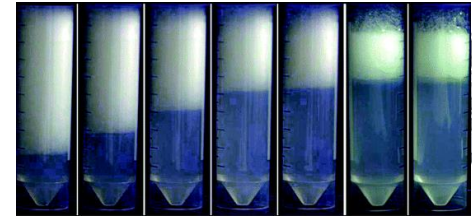
mechanical properties

low density

high specific area

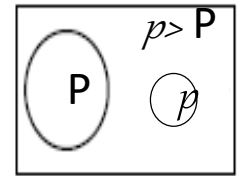
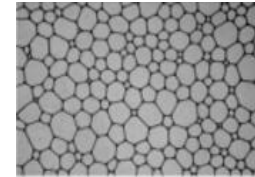
energy content: $A \cdot \sigma$

drainage



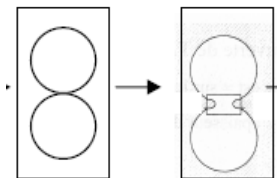
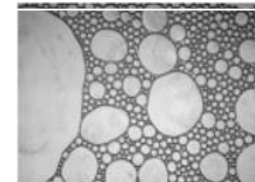
volume, liquid fraction \searrow

disproportionation



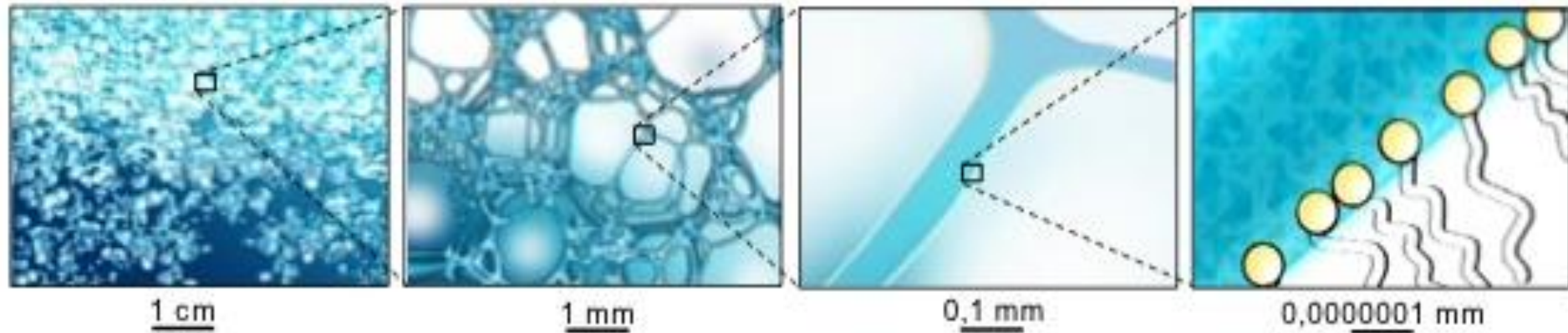
bubble size \nearrow

coalescence



bubble size \nearrow

Multiscale approach from foam to adsorption layer



foam: density, stability, rheology

bubble: size, shape, surface pressure

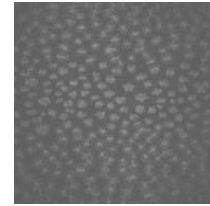
film: thickness, visco-elasticity, roughness

adsorption layer: adsorption kinetics, surface concentration, protein conformation and orientation, visco-elasticity, surface pressure

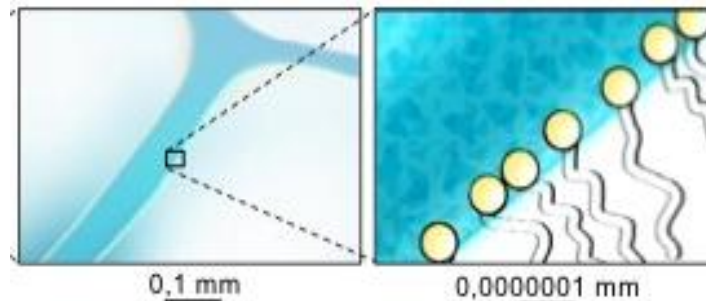
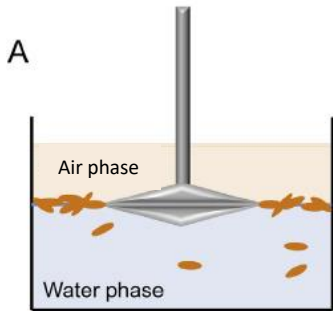
Interfacial measurements



Brewster angle microscopy
imaging ellipsometry

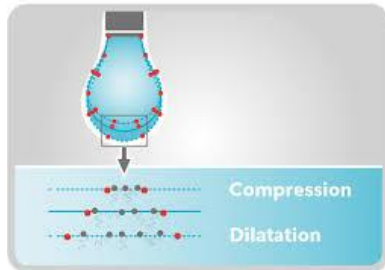


surface tension
shear rheology

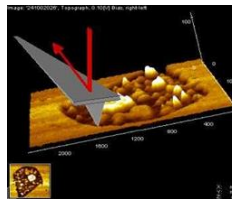


PM-IRRAS
molecular
conformation and
orientation

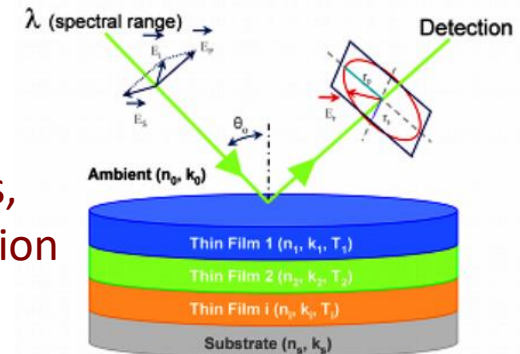
dilatational rheology



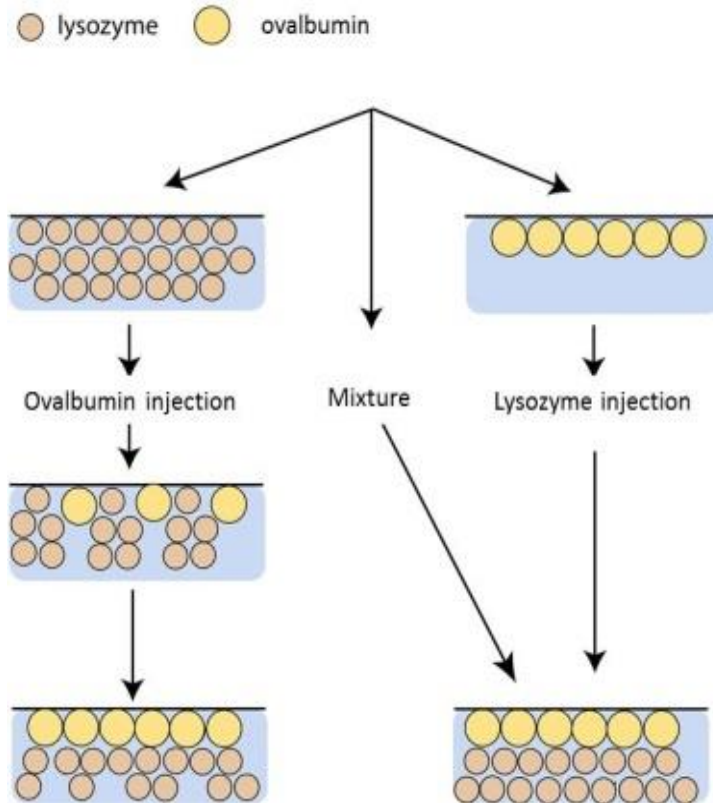
atomic force
microscopy
film thickness &
roughness



ellipsometry
adsorption kinetics,
surface concentration
excess



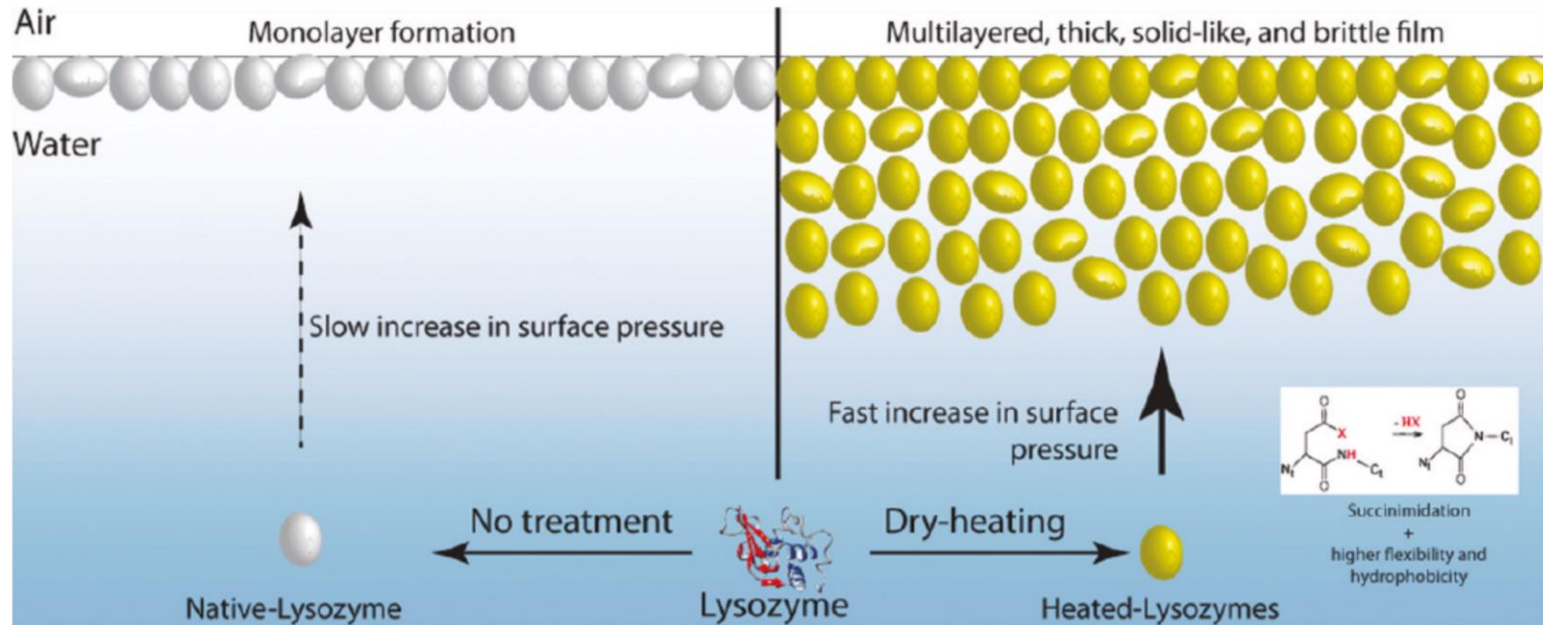
Interface as a competitive site for protein adsorption



- synergistic co-adsorption
- preferential protein assembly at the air-water interface
- stratified model, surface activity

Le Floch-Fouéré et al., 2009 ([doi:10/fxdc22](https://doi.org/10/fxdc22)), 2010 ([doi:10/d38gsz](https://doi.org/10/d38gsz))

Interface as an indicator of the changes in protein conformation



- minor changes in the protein stability dramatically impact the interfacial behavior
- dry-heating increases aggregation and propensity to self-association at the interface

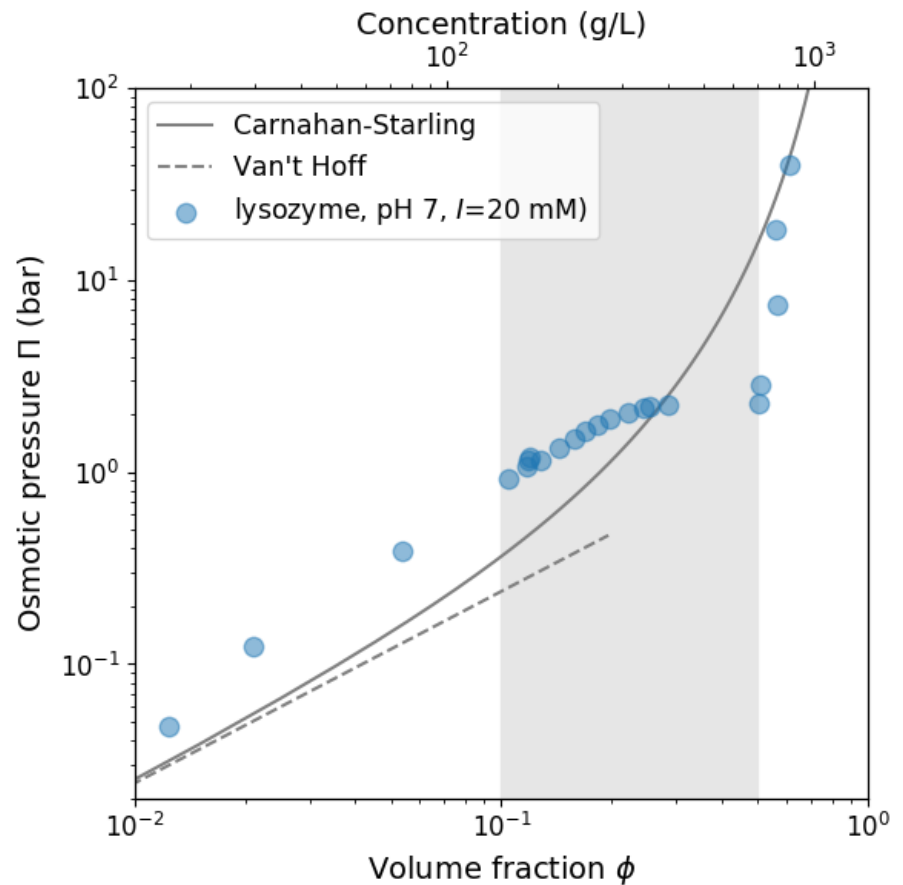
Desfougères et al., 2008 (doi:10/ck4w63), 2011 (doi:10/bfb25m)

Interface as a crowded system

- high local concentration in the interfacial film
- which contribution of crowding?
- osmotic pressure in concentrated solutions?

Interface as a crowded system

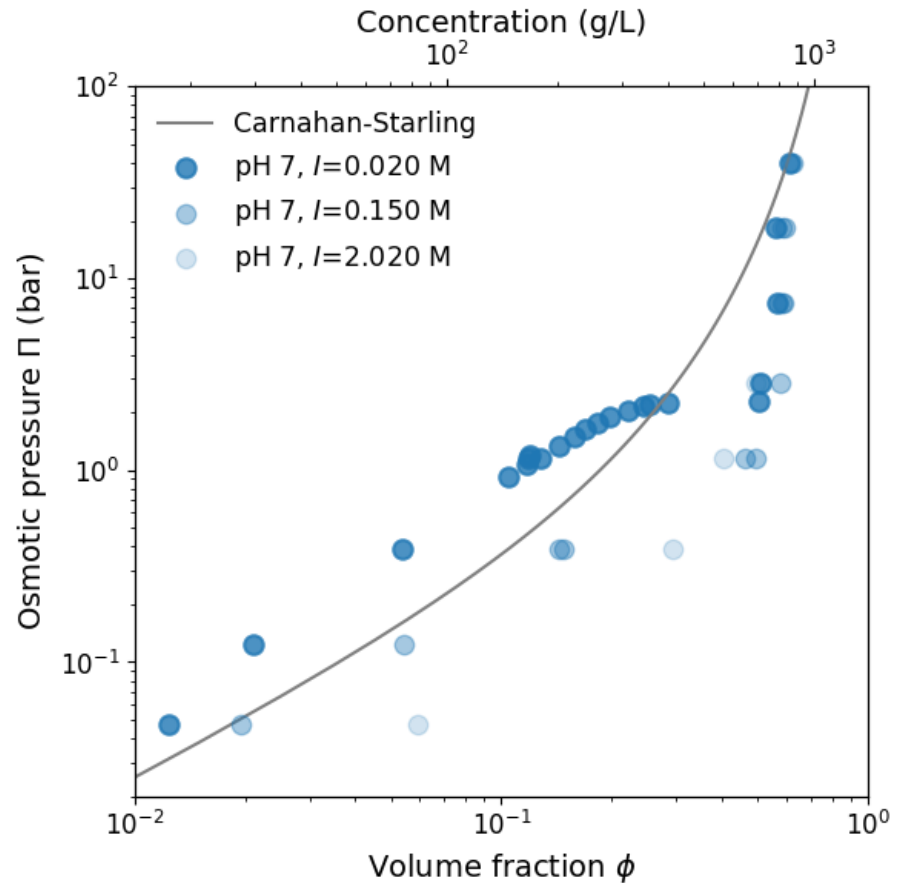
- phase transition: crystallisation



Pasquier et al., 2016 ([doi:10/bqqrz](https://doi.org/10/bqqrz))

Interface as a crowded system

- phase transition: crystallisation
- reversibility, therm. equilibrium
- electrostatic interactions



Pasquier et al., 2016 ([doi:10/bqqrz](https://doi.org/10/bqqrz))

Interface as a crowded system

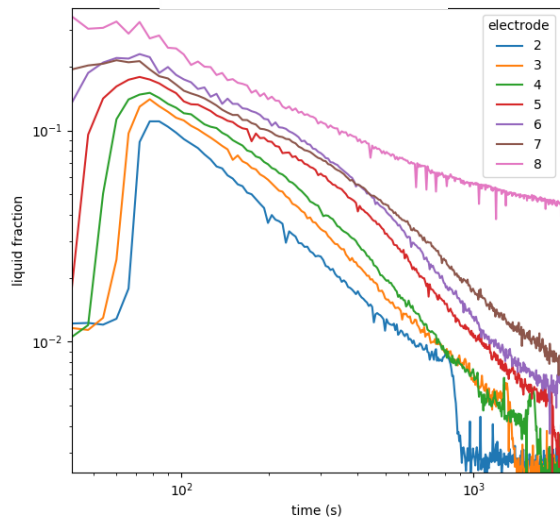
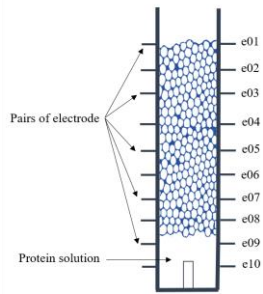
- correlation between EOS and interfacial behavior
- coupling between osmotic pressure gradients and transport
- advection
- ionic effects

From the interface to the foam

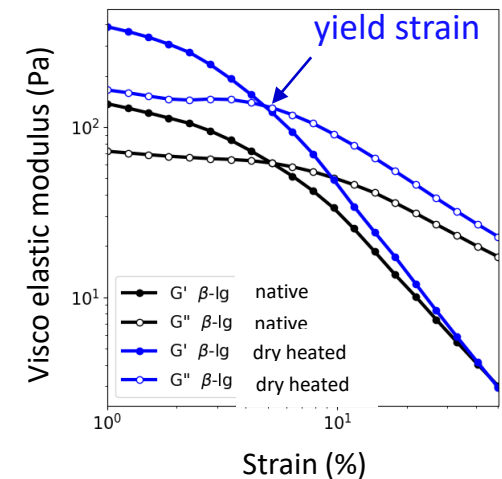
- relation of foaming properties to interfacial behavior?

Foam measurements

liquid volume fraction, drainage



foam rheology

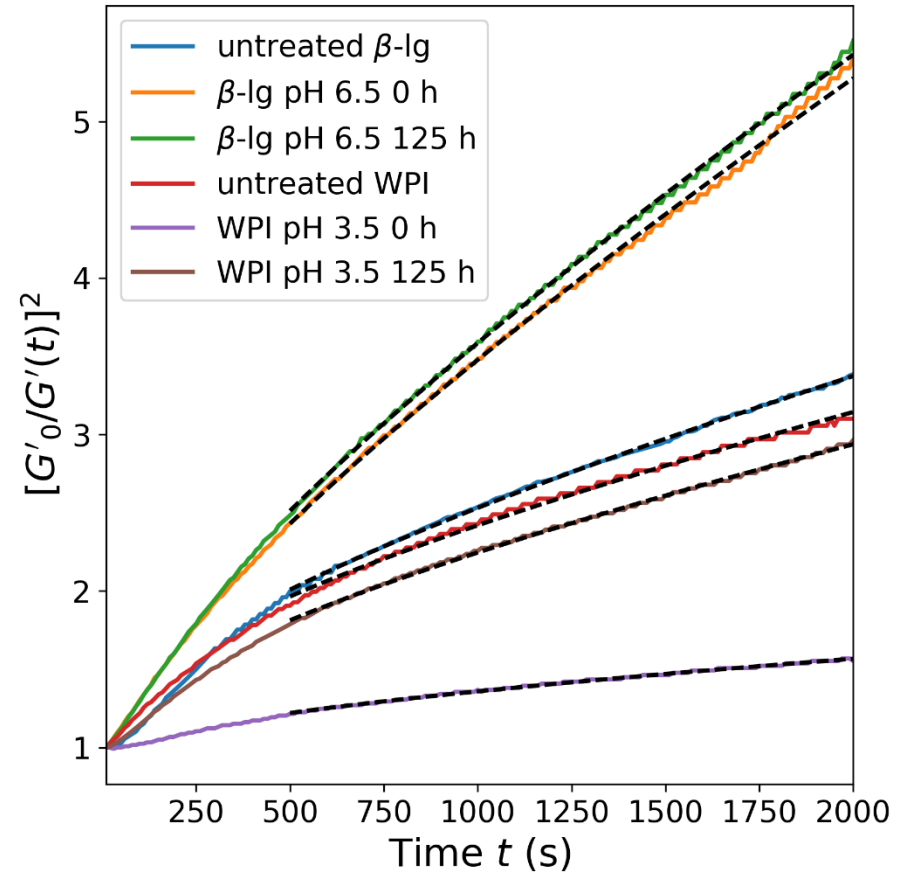


disproportionation

Audebert et al., 2019a ([doi:10/ctf8](https://doi.org/10.1016/j.cit.2019.04.008)), 2019b ([doi:10/cz9w](https://doi.org/10.1016/j.cit.2019.04.009))

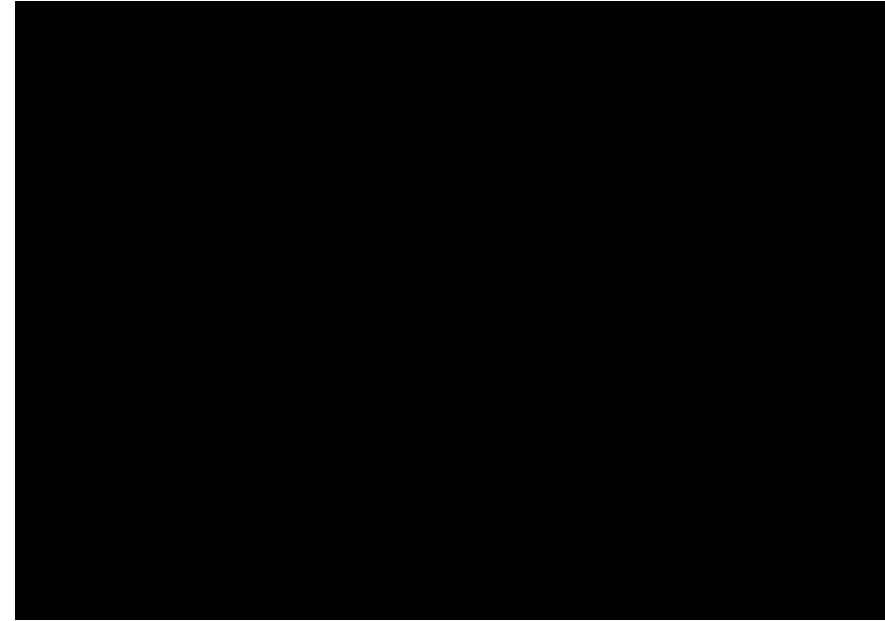
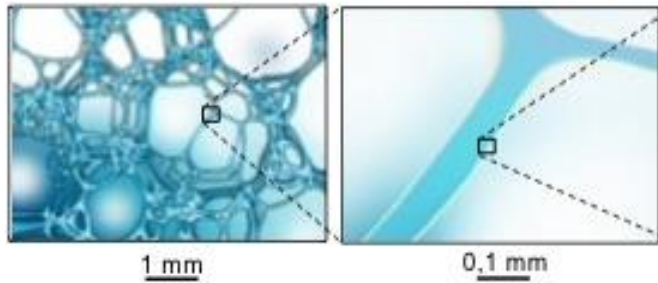
Foam rheology & disproportionation

- $G' = \frac{\sigma}{R} g(\Phi_l)$
- $R \sim \sqrt{t}$

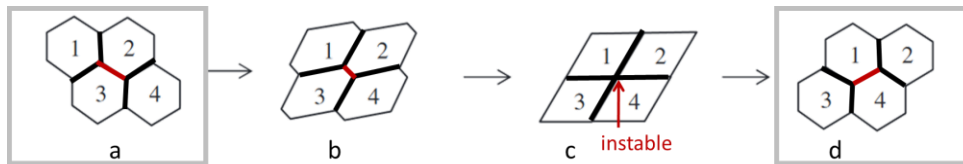


Audebert et al., 2019b ([doi:10/cz9w](https://doi.org/10.1016/j.cj.2019.03.009))

Bubble film dynamics

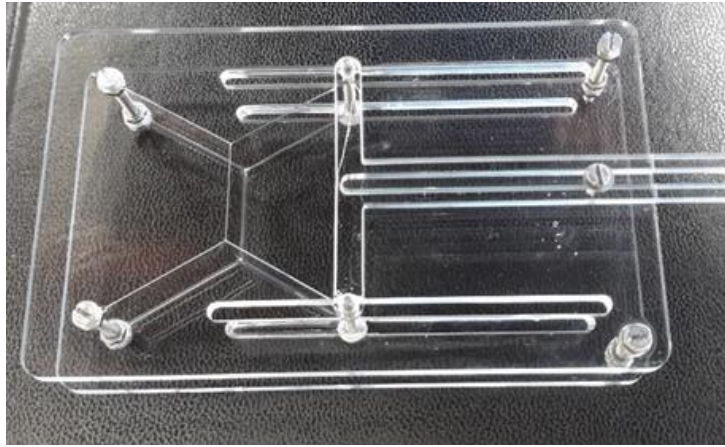


T1 topological rearrangements

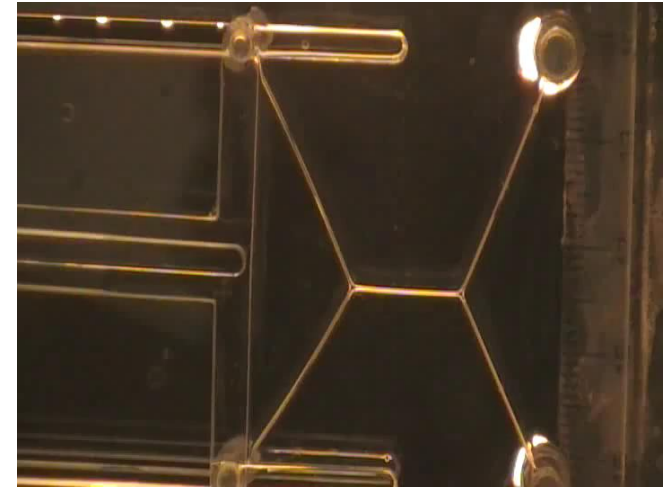


Krüess GmbH

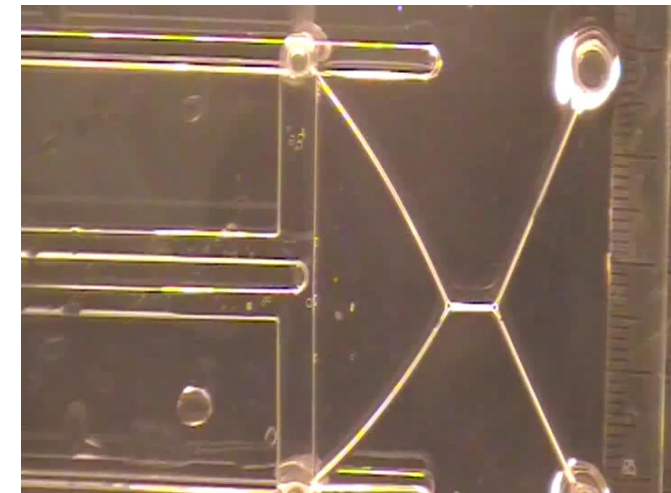
Bubble film dynamics



native β -lg
1.5 s



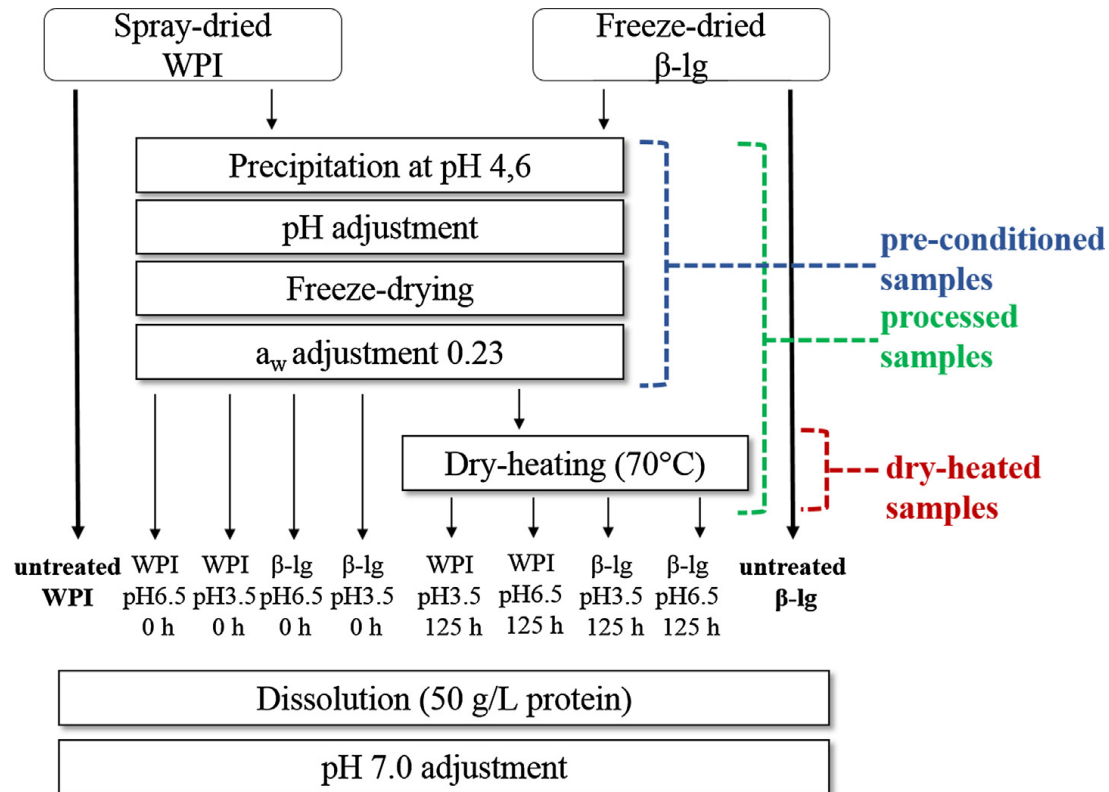
time for 90%
of final length



dry heated β -lg
4.6 s

Audebert et al., 2019 ([doi:10/cz9w](https://doi.org/10.1016/j.cj.2019.01.001))

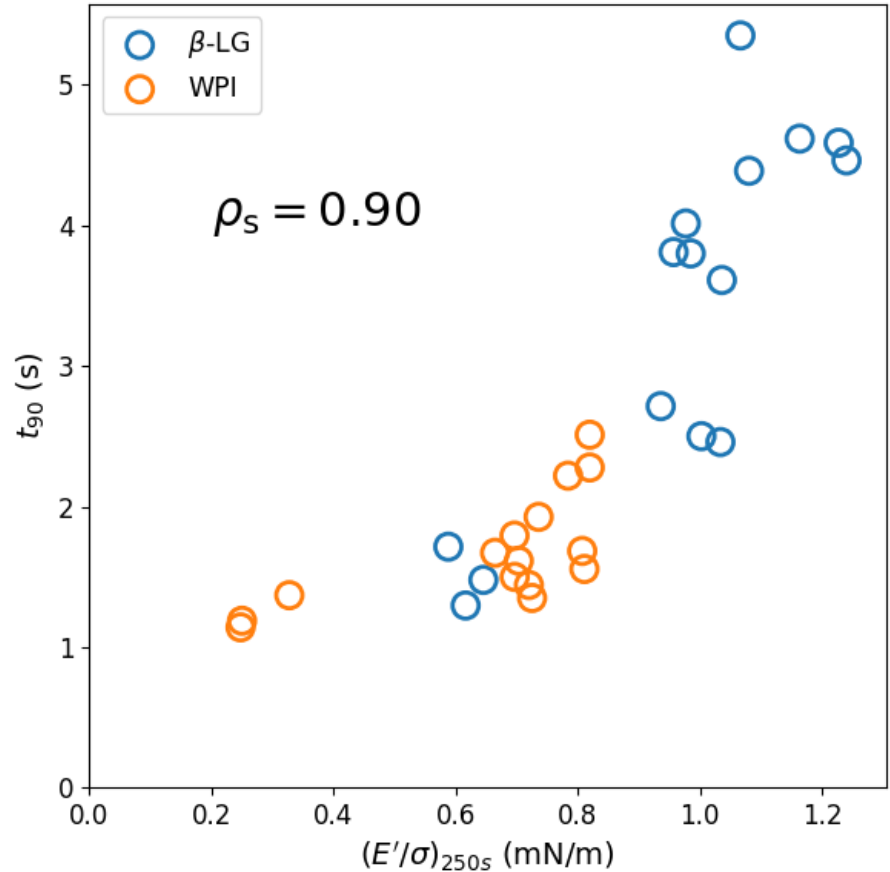
Protein modification



Audebert et al., 2019a ([doi:10/ctf8](https://doi.org/10/ctf8)), 2019b ([doi:10/cz9w](https://doi.org/10/cz9w))

Multiscale correlations

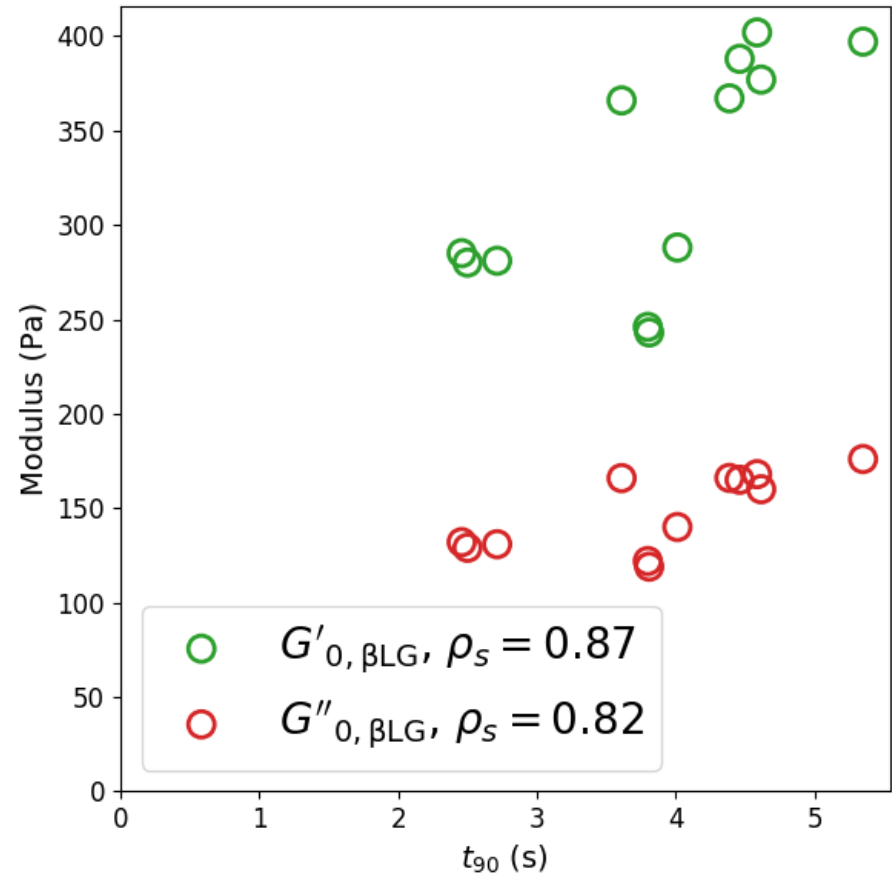
- interfacial rheology & T1



Audebert et al., 2019b ([doi:10/cz9w](https://doi.org/10.1016/j.cj.2019.03.009))

Multiscale correlations

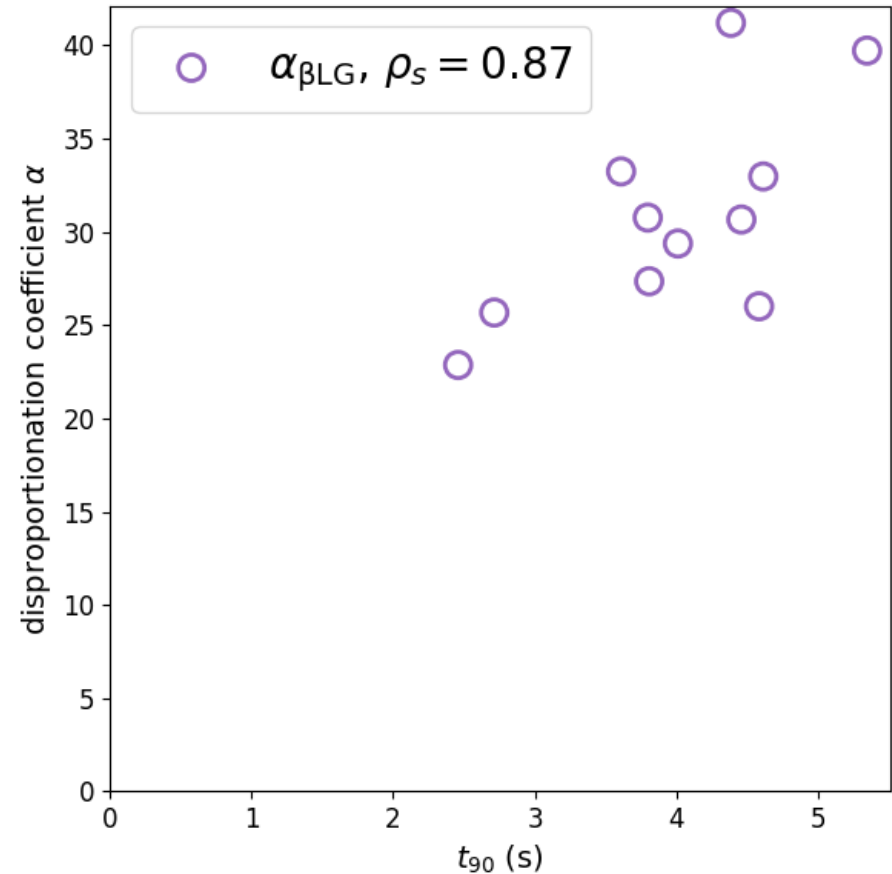
- interfacial rheology & T1
- T1 & foam rheology



Audebert et al., 2019b ([doi:10/cz9w](https://doi.org/10.1016/j.cj.2019.03.001))

Multiscale correlations

- interfacial rheology & T1
- T1 & foam rheology
- T1 & foam disproportionation



Audebert et al., 2019b ([doi:10/cz9w](https://doi.org/10.1016/j.cj.2019.03.009))

Conclusion

- film dynamics as an intermediate scale between interface and foam
- kinetics, early steps of interfacial film formation
- foam rheology as a functional criterion
- sensitivity to protein structure and stability
- food proteins: open questions in foam / colloid physics
- interdisciplinarity as a necessity

Zaccagnino et al., 2018 ([doi:10/cw2k](https://doi.org/10.1016/j.cw2k))

Acknowledgements

- *Sylvie Beaufiles (IPR)*
- *Arnaud Saint-Jalmes (IPR)*
- *Cécile Le Floch-Fouéré*
- *Alexia Audebert (PhD)*
- *Coralie Pasquier (PhD)*
- *Yann Desfougères (PhD)*
- *Antoine Bouchoux (LISBP)*
- *Bernard Cabane (CBI)*
- *Mikael Lund (Lund univ.)*
- *Simon J. Cox
(Aberystwyth univ.)*
- *Lay-Theng Lee (LLB)*



MERCI



***THANK YOU FOR
YOUR ATTENTION***

Key publications

- Audebert, A. et al. (2019) *J. Food Eng.* 242, 153–162
- Audebert, A. et al. (2019) *J. Colloid Interface Sci.* 542, 222–232
- Boire, A. et al. (2019) *Annu. Rev. Food Sci. Technol.* 10, 14.1–14.19
- Pasquier, C. et al. (2016) *Phys. Chem. Chem. Phys.*, 18, 28458–28465
- Desfougères, Y. et al. (2011) *Biomacromolecules*, 12, 156–166
- Desfougères, Y. et al. (2011) *Langmuir*, 27, 14947–14957
- Le Floch-Fouéré, C. et al. (2010) *Food Hydrocoll.*, 24, 275–284
- Le Floch-Fouéré, C. et al. (2009) *Food Hydrocoll.*, 23, 352–365