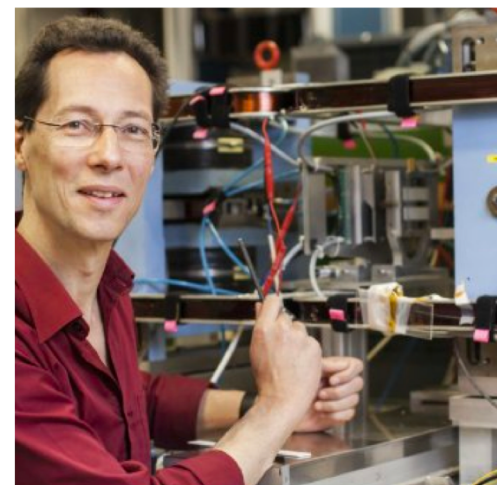


Neutron Scattering for Sustainable Food Production



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brightness²



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Neutron Scattering for Sustainable Food Production

The challenge of real systems



Food production 20% CO₂



- Optimisation processing
Homogenisation, cooling, heating
- Sustainable ingredients
Plant based proteins
- New ingredients need new processes
- Rational redesign requires quantitative structural information

Neutrons: quantitative information

3 **real** examples

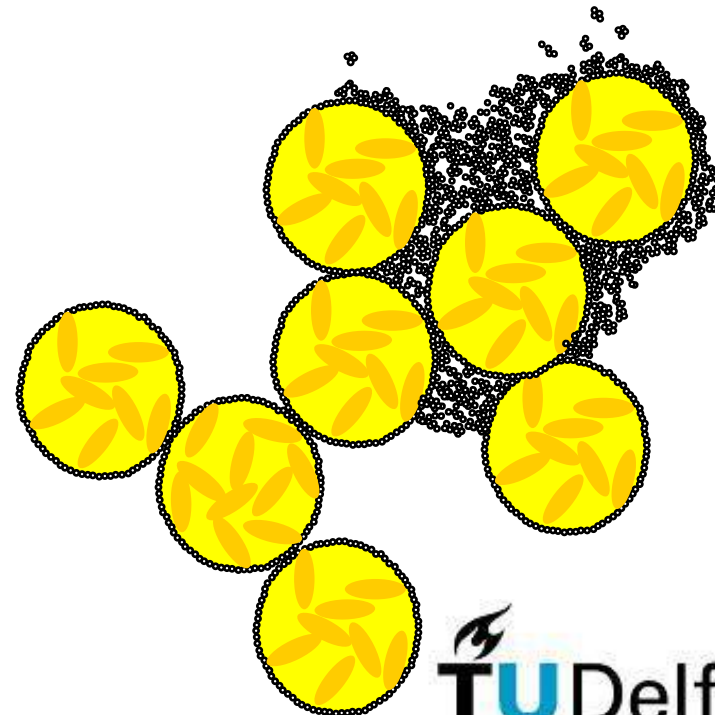
- Fresh cheese
 - Creaminess
- Meat replacers based on shear
 - Fibrousness
 - Texture
 - Dynamics
- Degumming plant oils
 - Water content



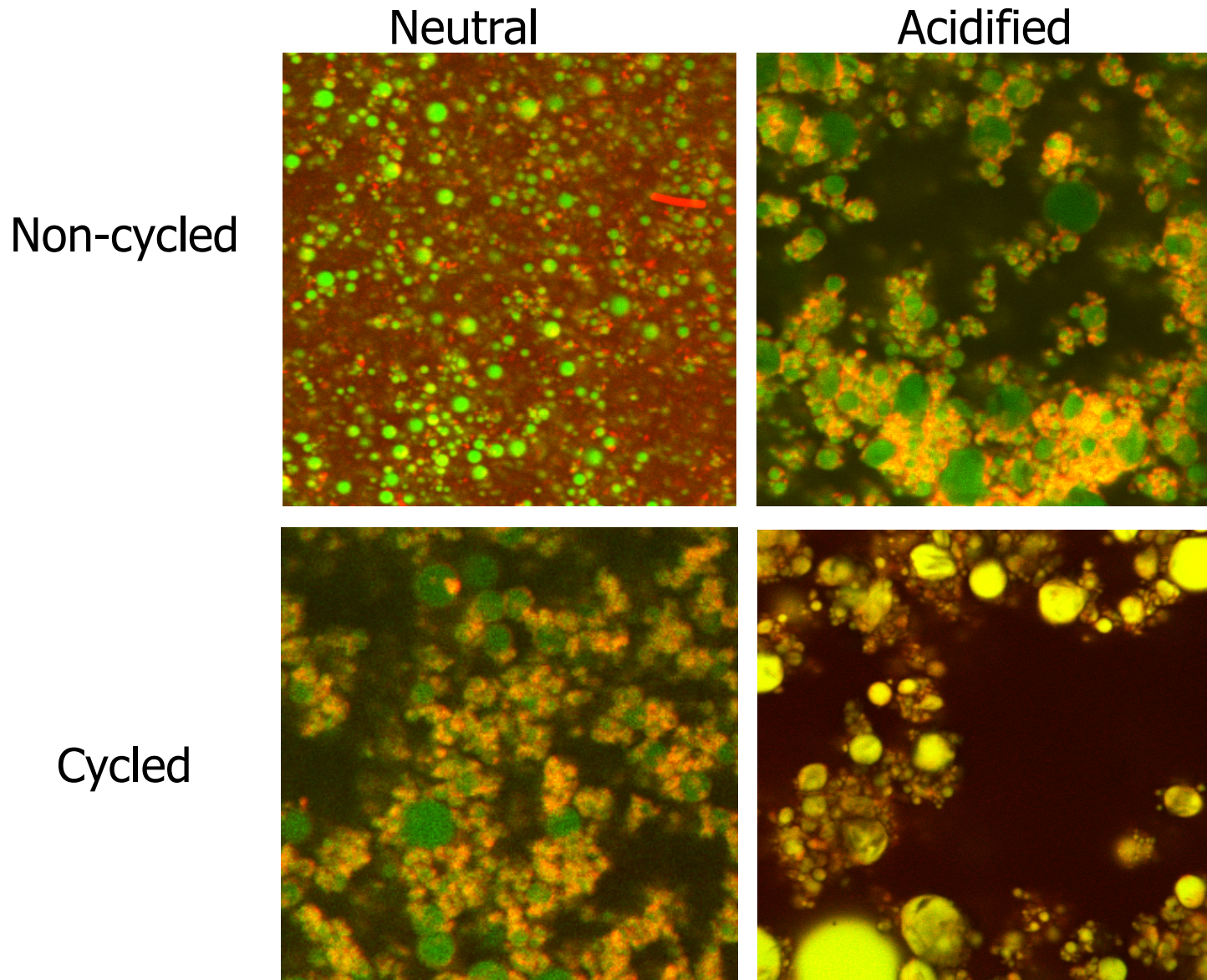
Texture fresh cheeses essential mouth feel and shelf life

Fresh cheese products complex microstructure:
elements of different size and properties:

- Fat droplets, stabilised by protein
- Fat droplet aggregates
- Protein aggregates



Effect of temperature cycling and preparation

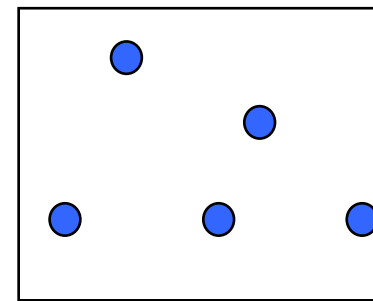
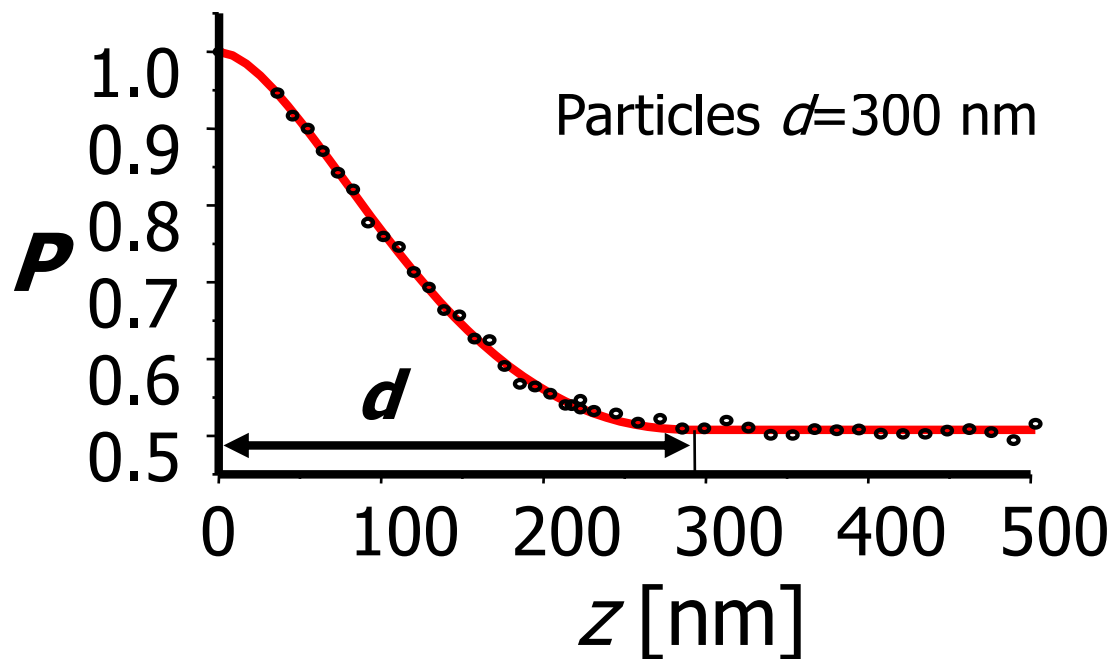


- Qualitative
- Surface

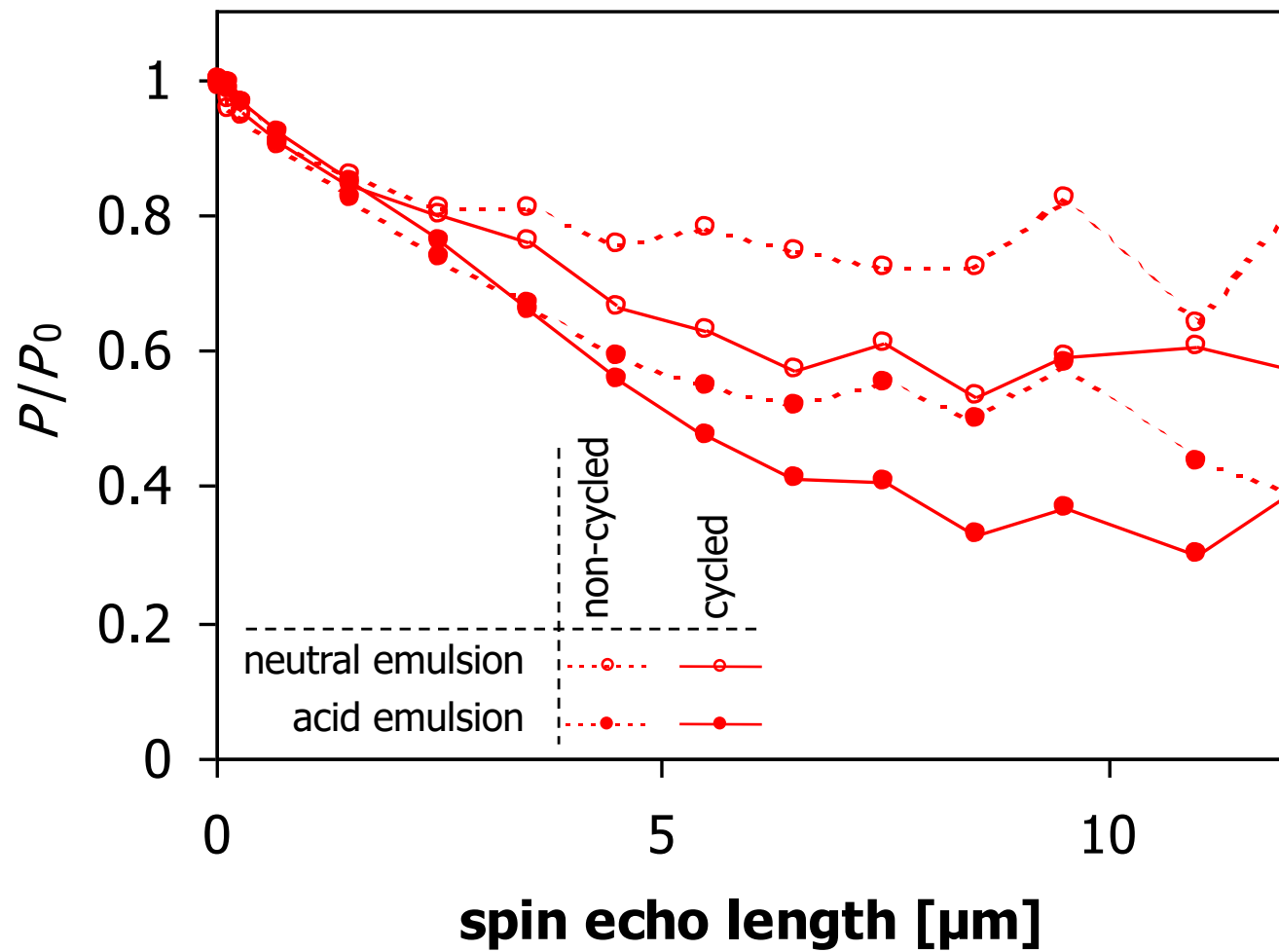
CSLM image of pre-heated neutral/acid non-cycled/cycled 4% WPC / 30% fat emulsion gels prepared by homogenisation at 30 bar.

image size 66 x 66 μm

Spin-echo small-angle neutron scattering: Density correlation function micron scale

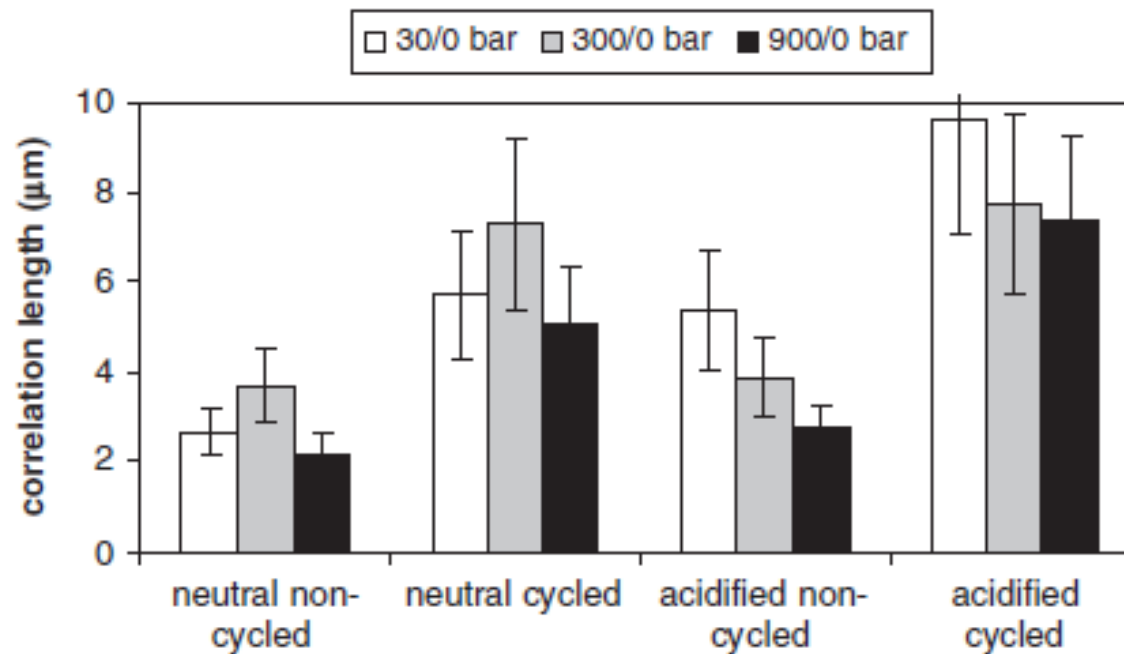


Effect of processing: cycled vs non-cycled / neutral vs acidified



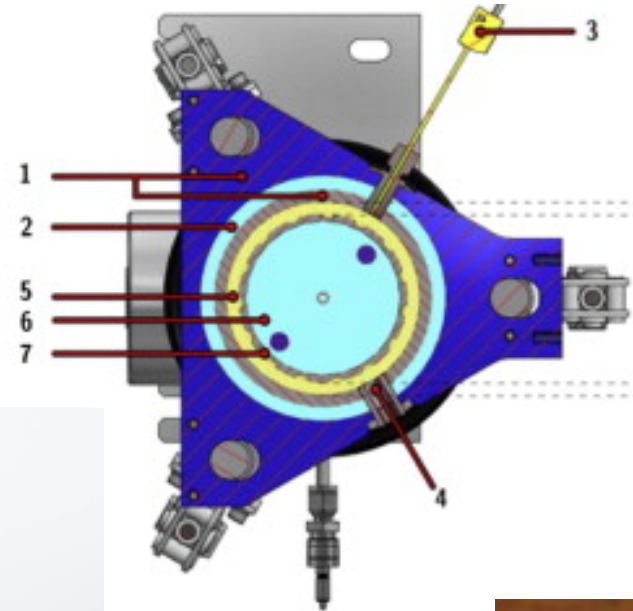
Optimal process parameters from neutrons creamy fresh cheese

- Quantitative relation production method with structure
- Rational redesign process to save energy

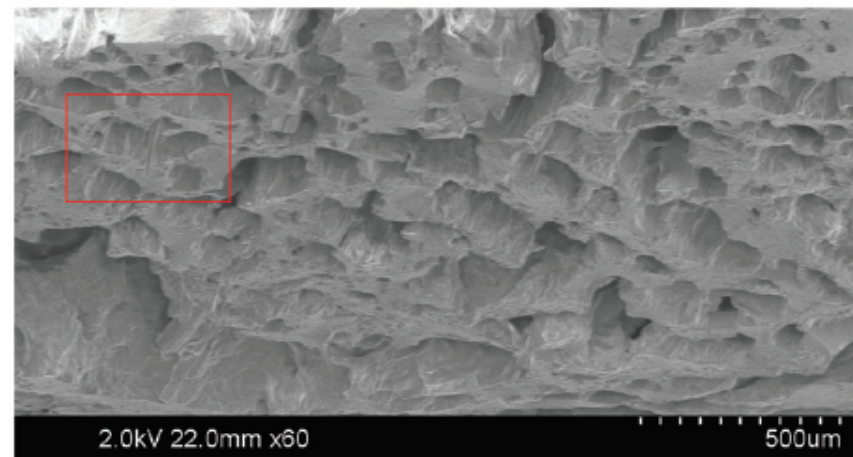
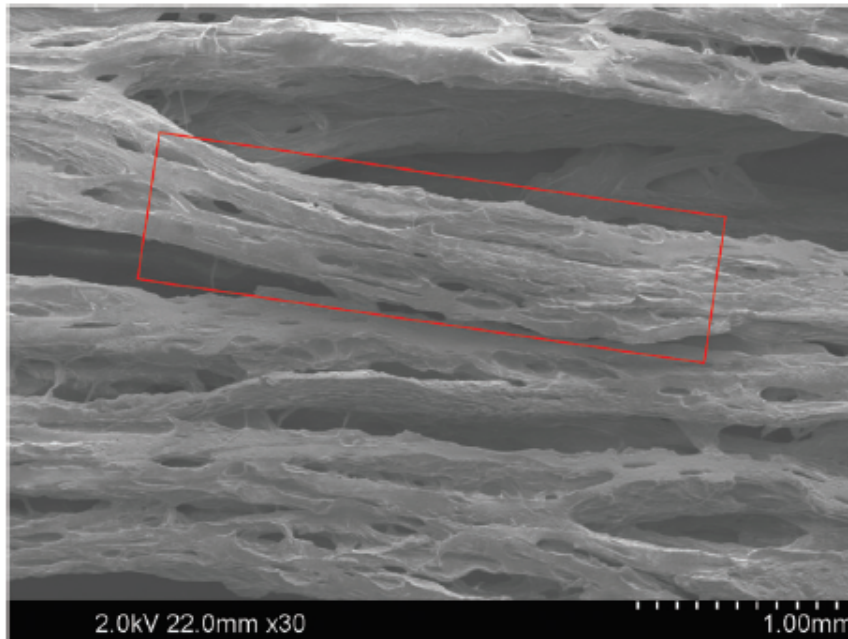
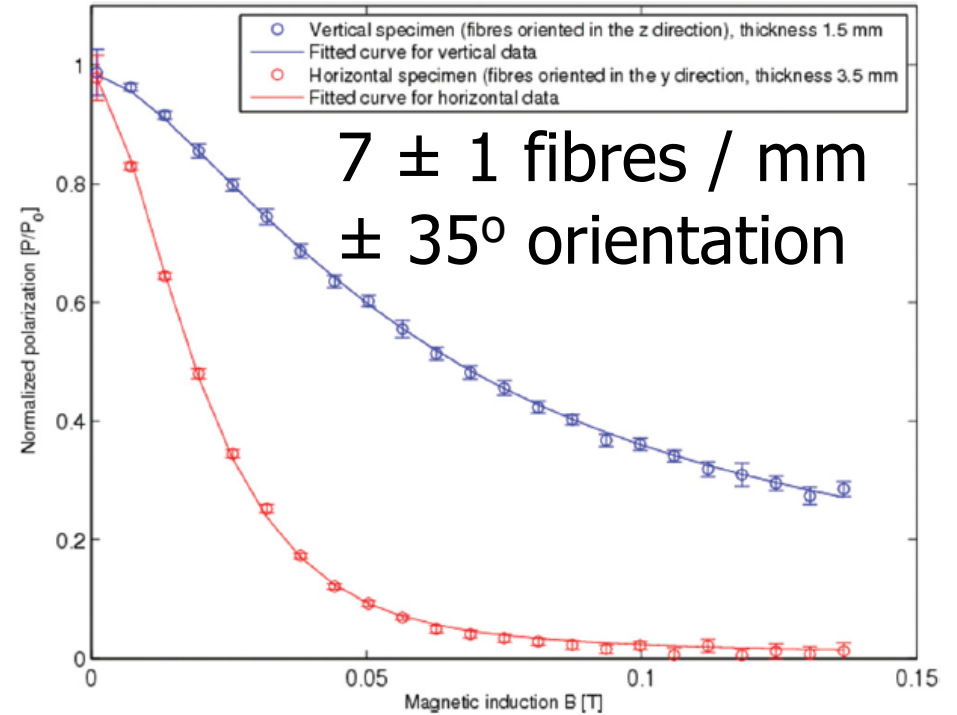
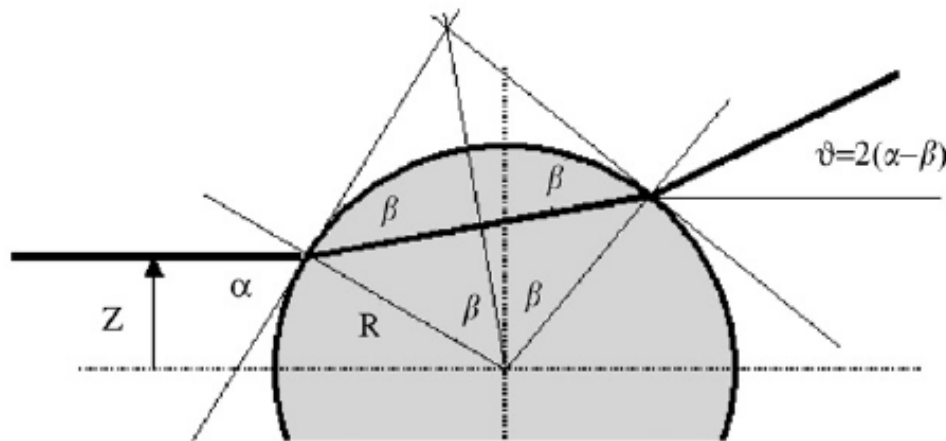


Vegan steak

Mechanism of fibre formation of sheared plant proteins?

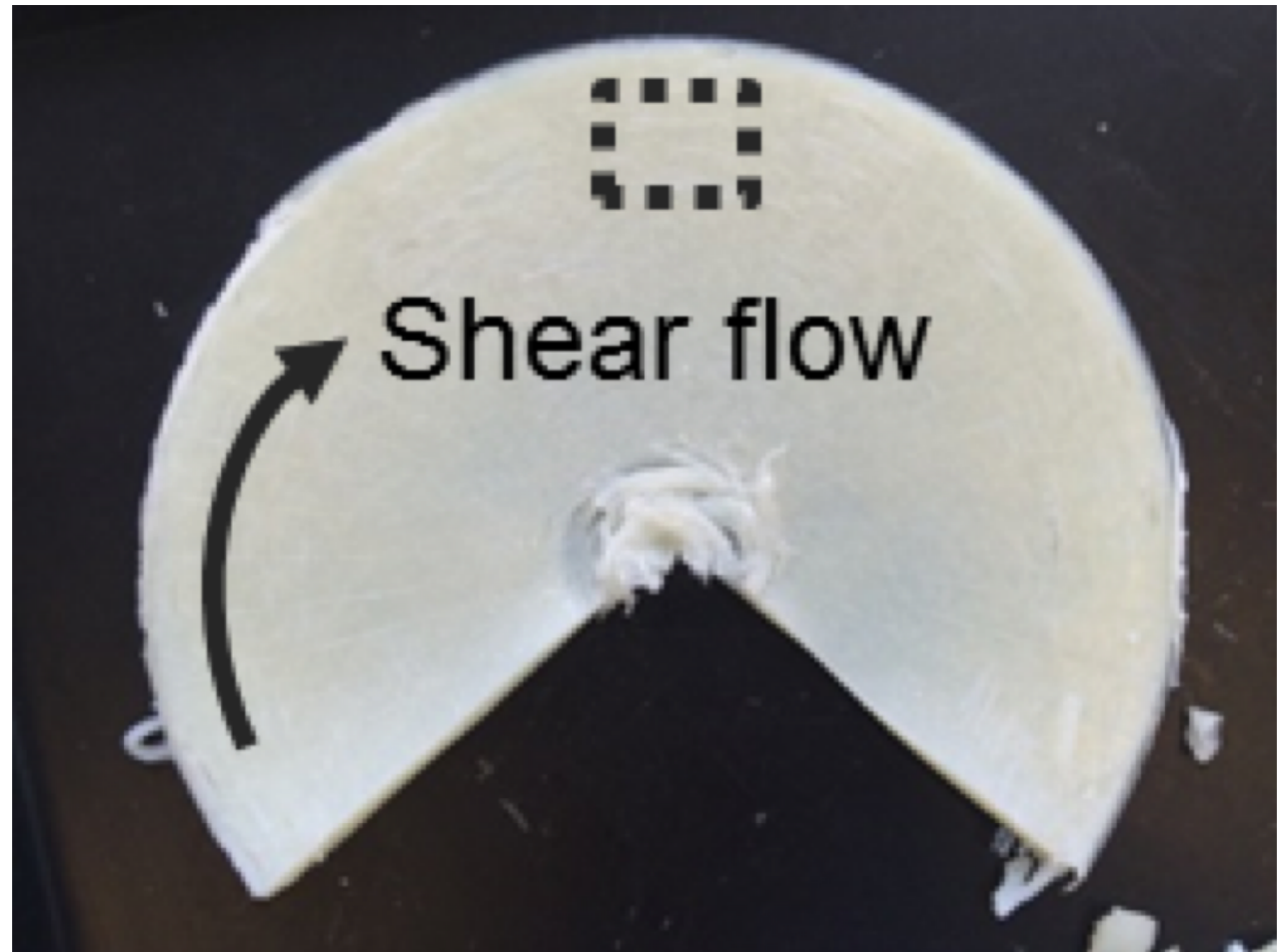


Neutron refraction: # fibres + orientation



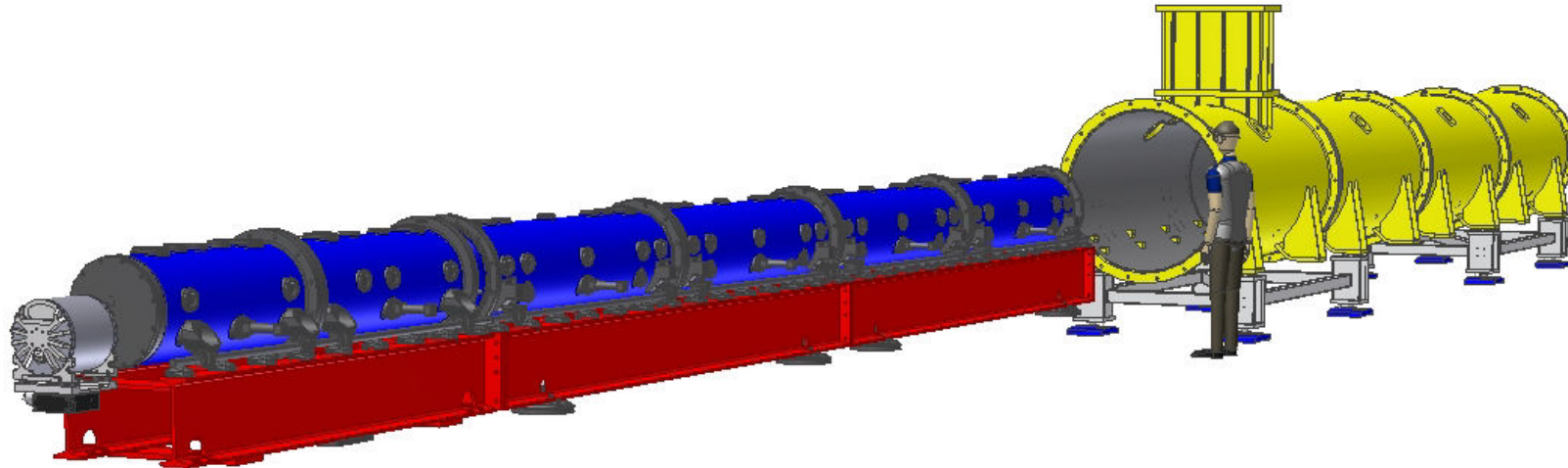
At which length scale starts anisotropy?
Shear rate and time?

Calcium
caseinate

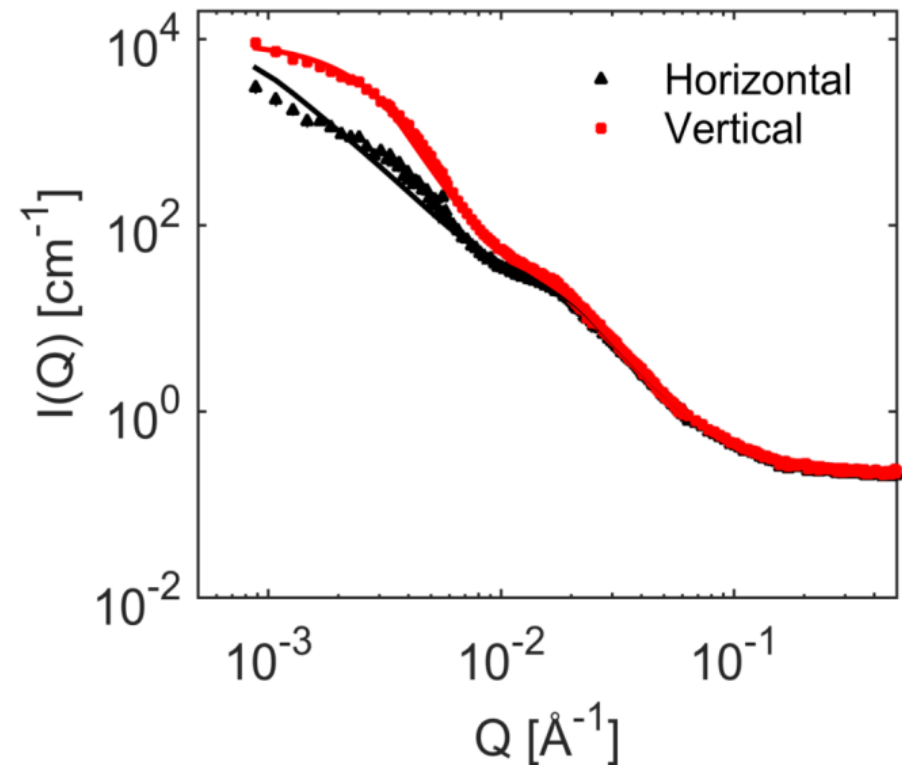
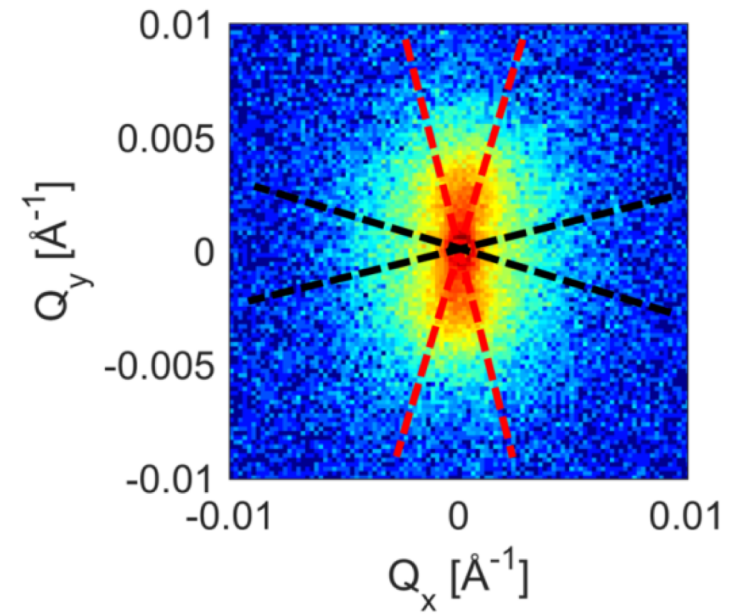
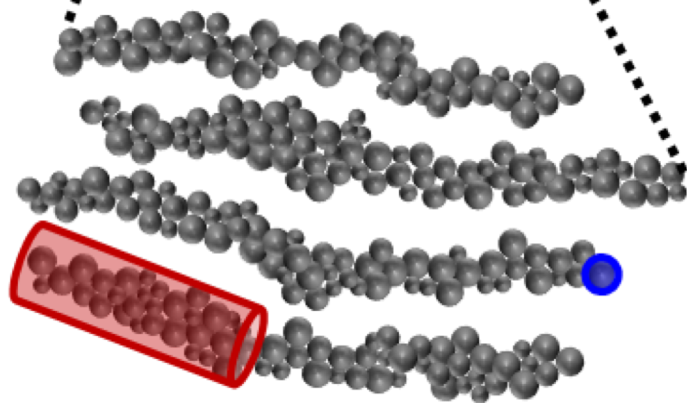
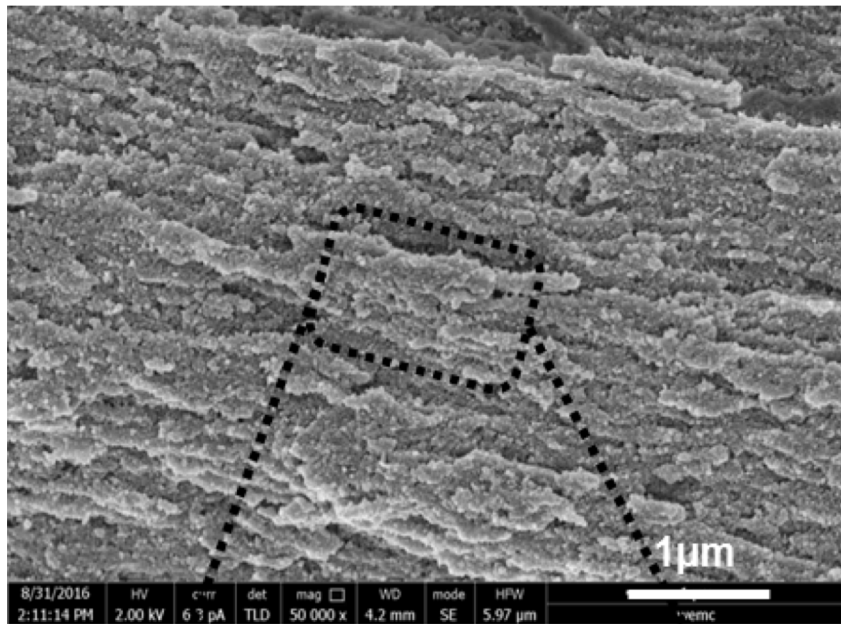


Small-angle neutron scattering SANS

- Structure length scales 1-1000 nm

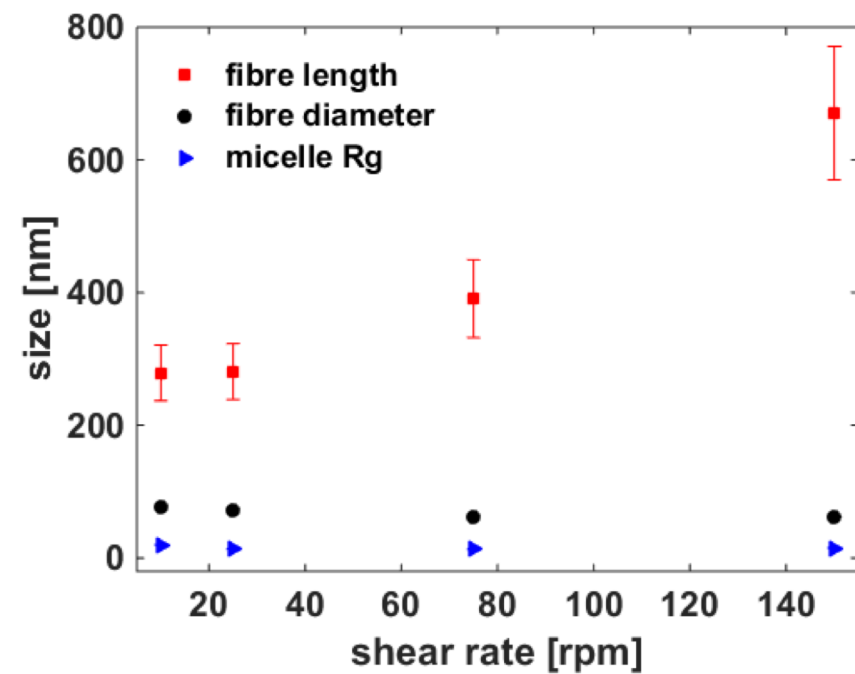
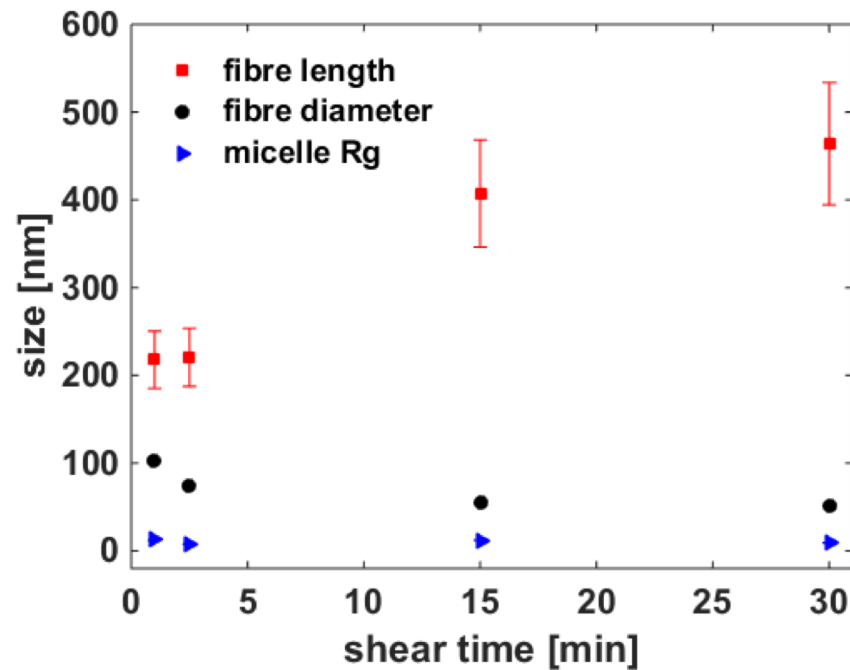


SANS: Anisotropy starts above micelles



Need sufficient shear time and rate for fibres

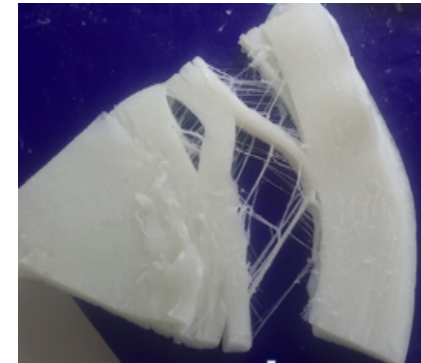
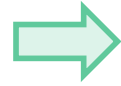
Anisotropy starts above 20 nm



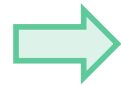
Which protein properties give good fibre texture?



Spray dried

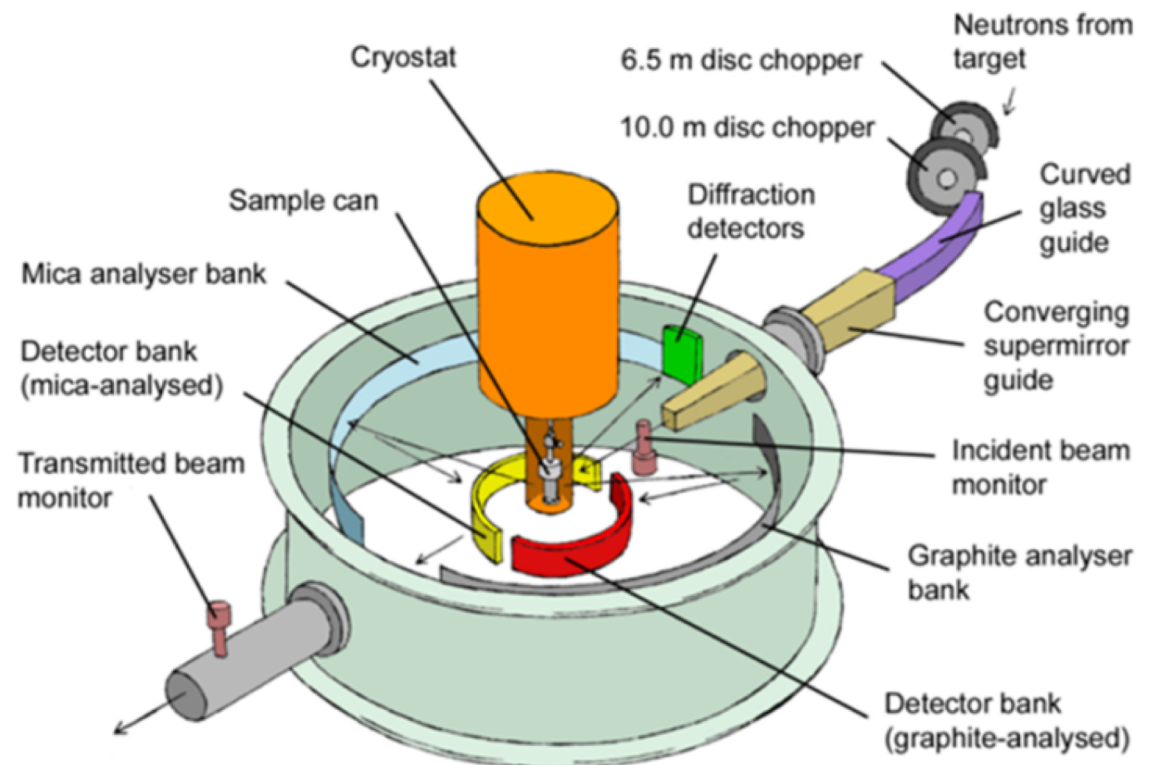


Roller dried

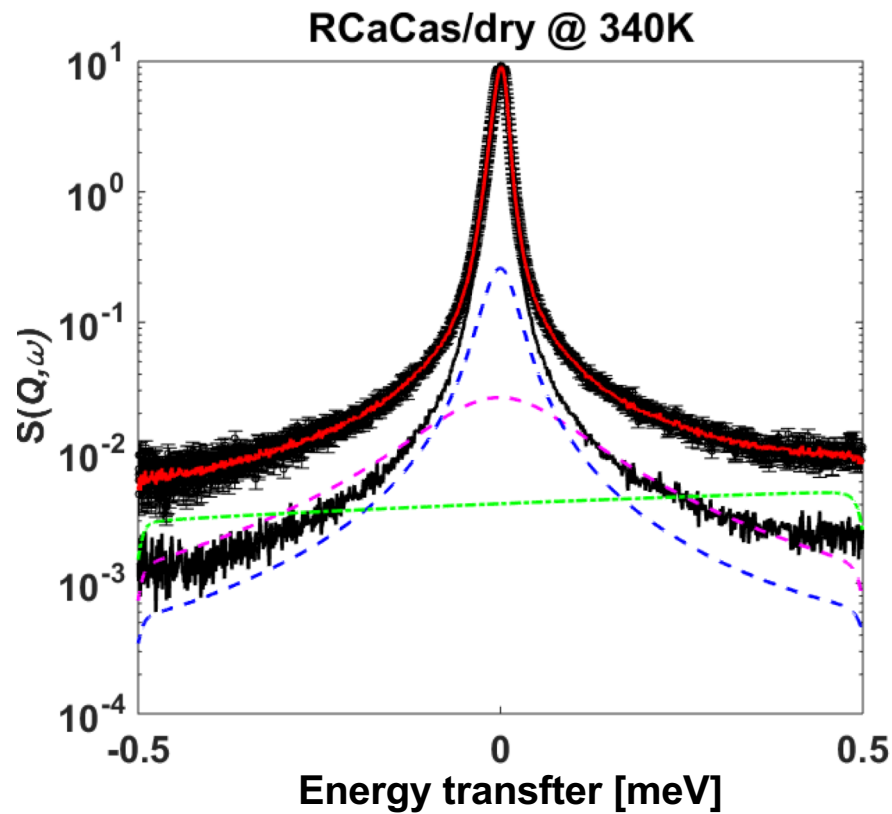


Do microscopic dynamics influence fibre formation?

- Spray dried and roller dried calcium caseinate
- Hydrated to H₂O or D₂O
- Quasi Elastic Neutron Scattering



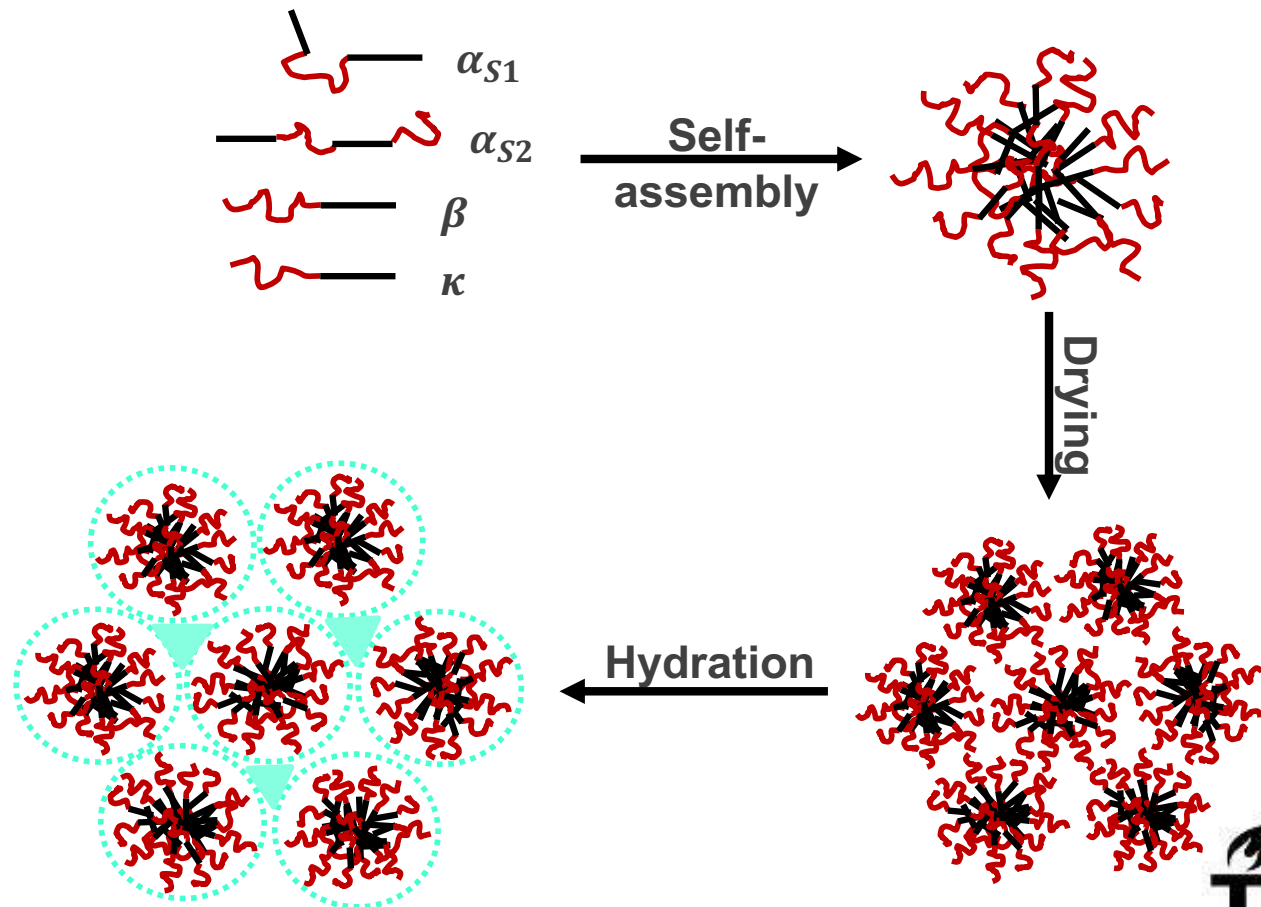
Dynamics from Quasi Elastic Neutron Scattering



- Delta function
- Lorentzian function
- Lorentzian function
- .- Linear background

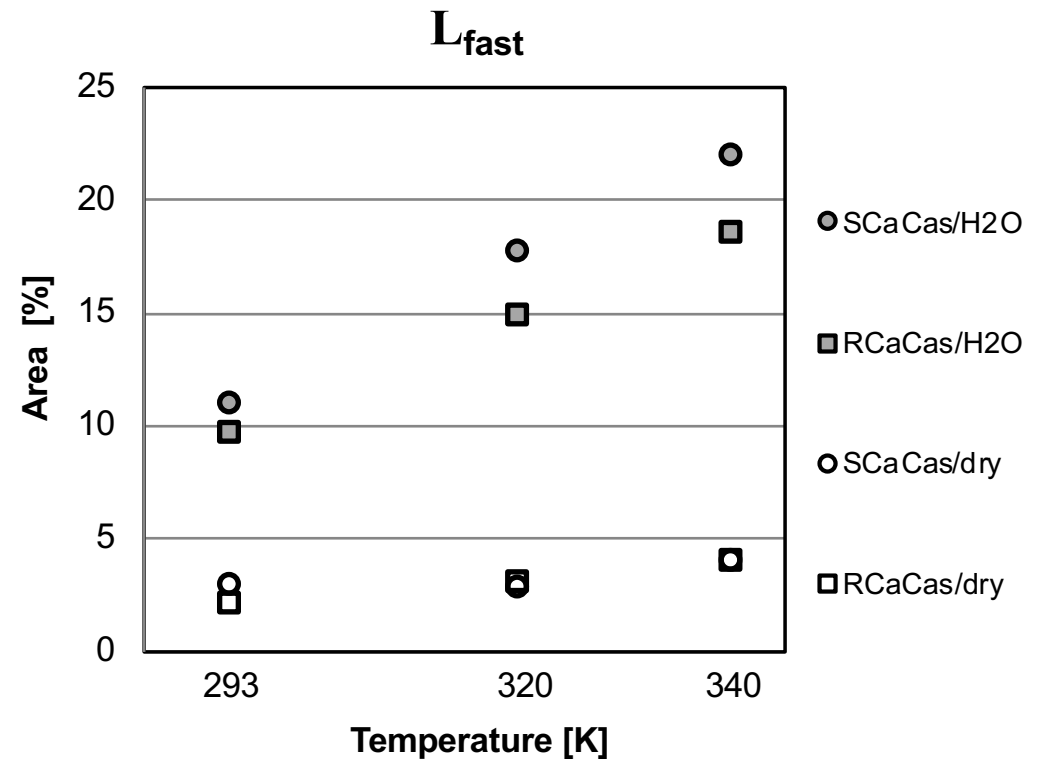
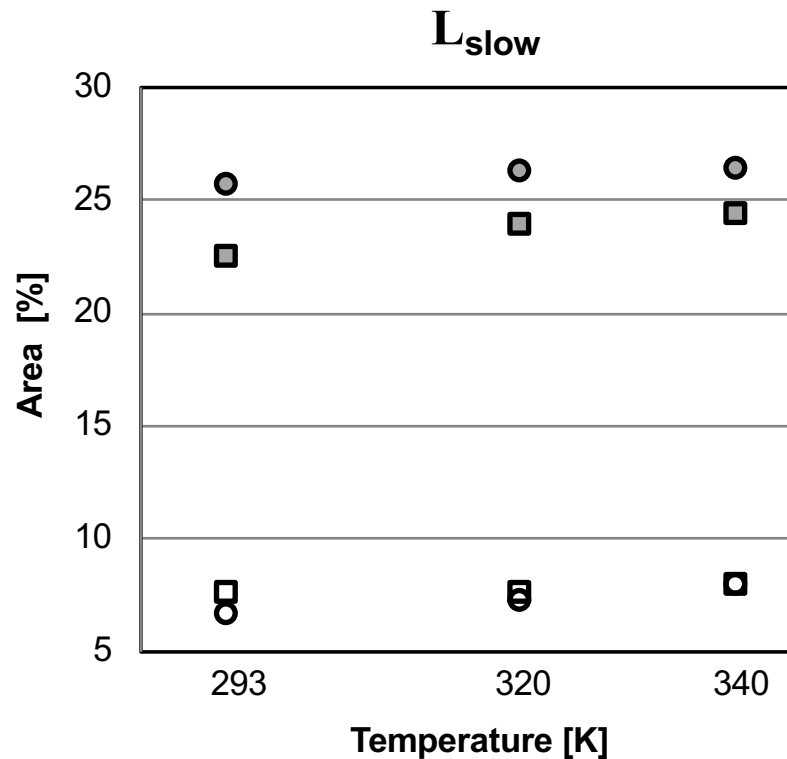
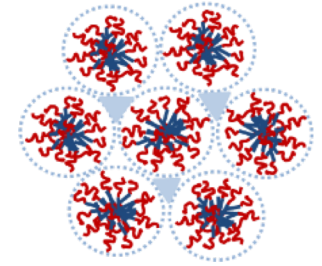
Slow and fast movements

- Narrow Lorentzian (slow motion 20 ps)
Internal protein groups
- Broad Lorentzian (fast motion 3 ps)
External protein groups



Spray dried more movement

Mobility proteins relevant fibres

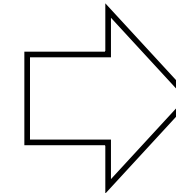
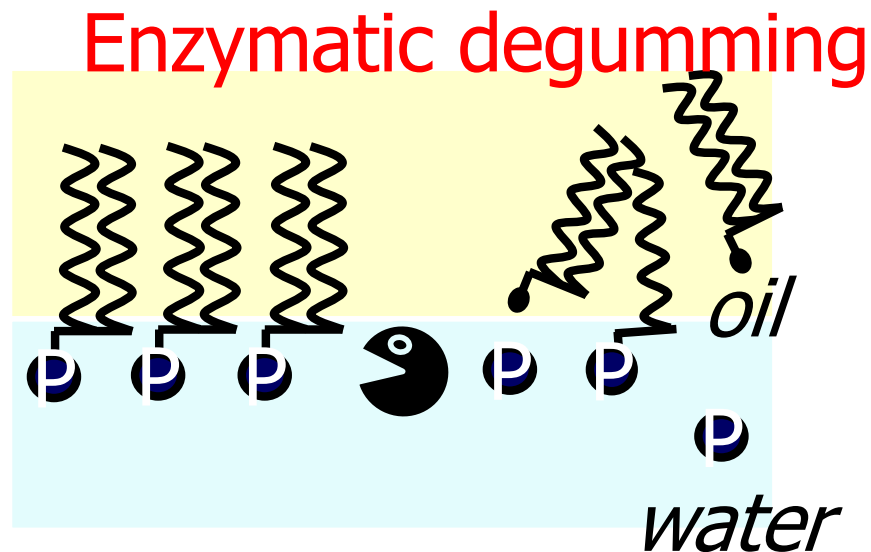
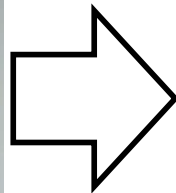
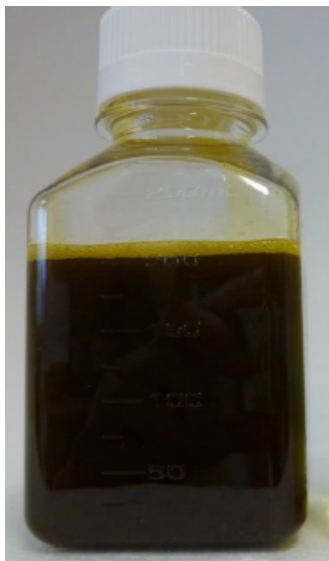


Degumming of organic oil

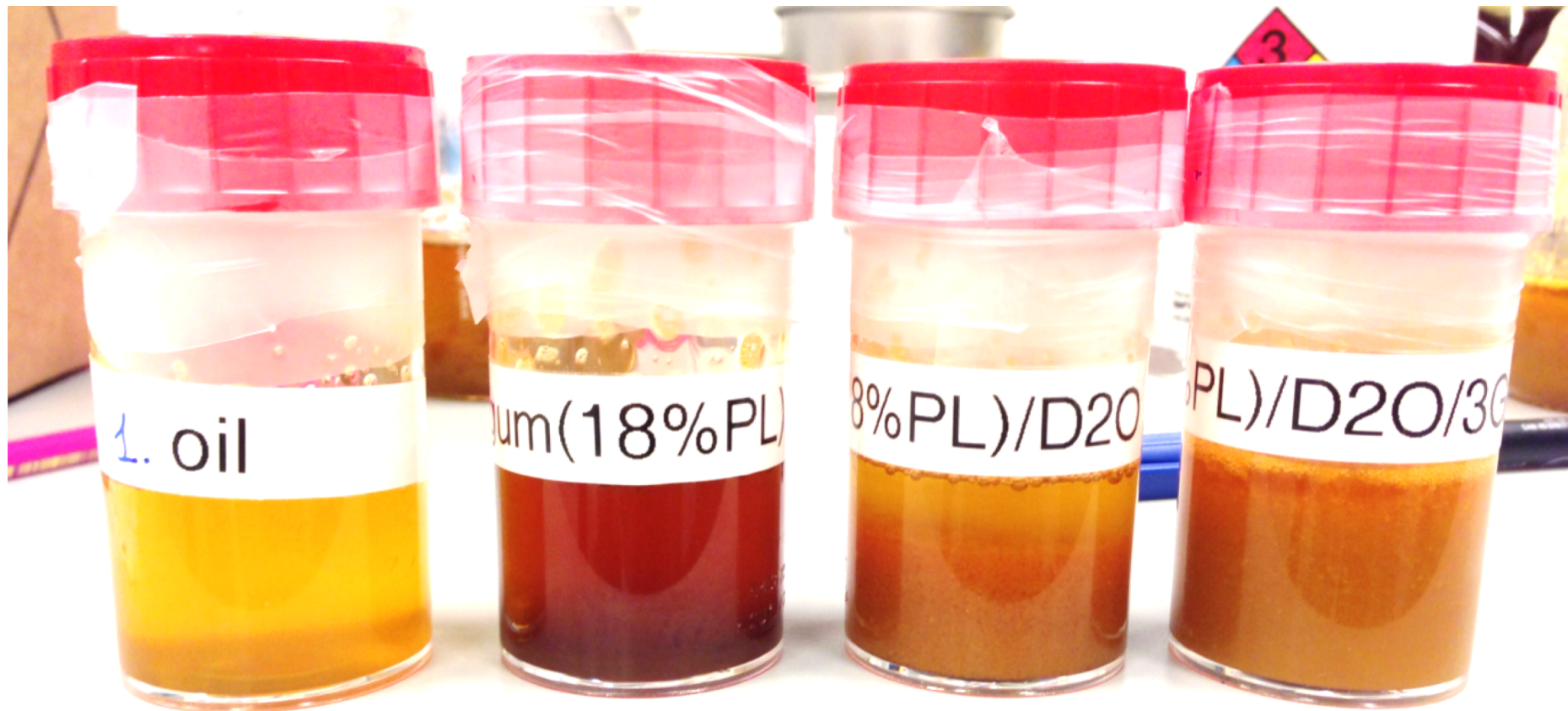
Costs a lot of water, use enzymes?

Crude seed oil

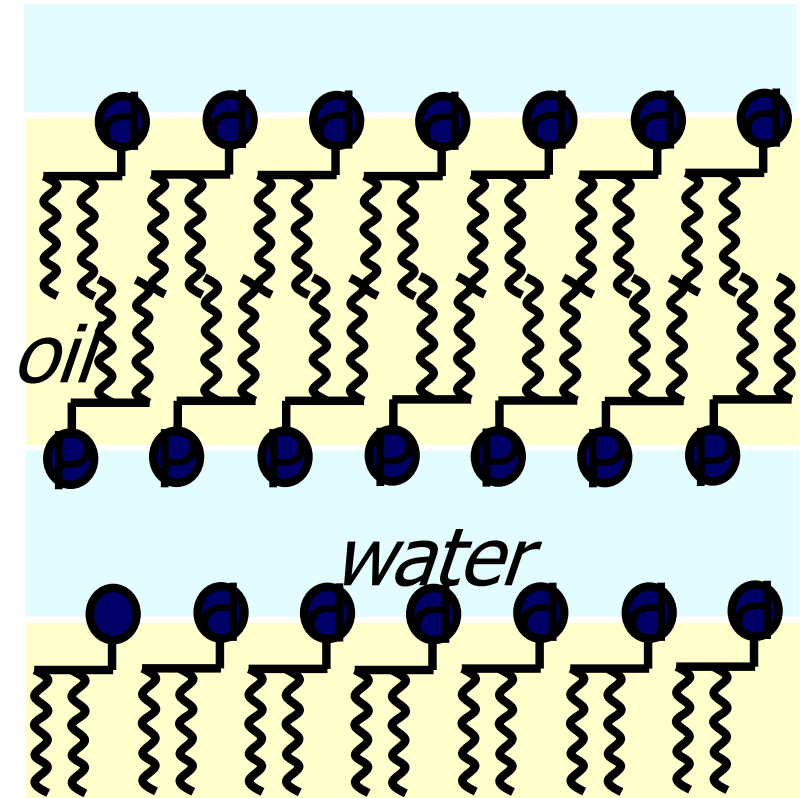
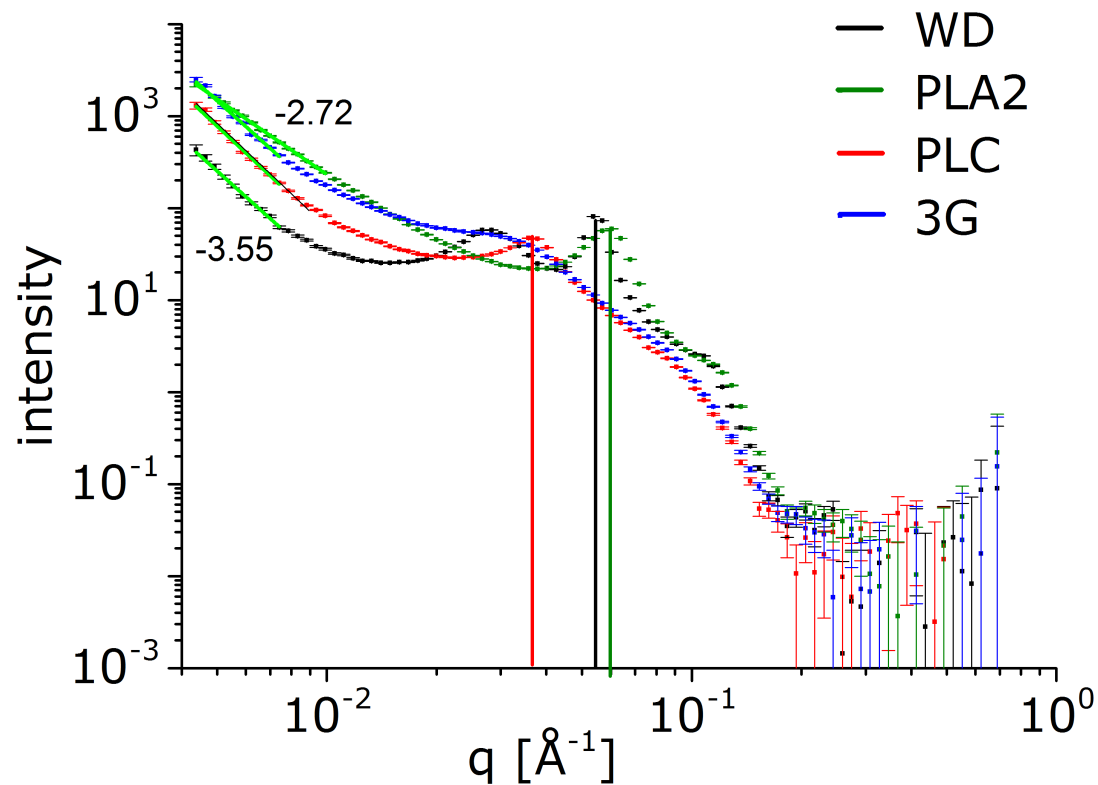
Edible oil



What are the phospholipid/oil/water mesostructures?



SANS: layered structure quantifies water fraction



- Quantification of di- and triglycerides in gum phase
- PLA2 most efficient enzyme

Neutrons scattering **real** food systems for sustainable production

- Quantitative results for rational redesign processing
- Future: in-situ kinetic measurements to follow processes
 - Sample environment
 - Data-analysis real materials
 - High flux



Acknowledgments

- *Effect of processing on droplet cluster structure in emulsion gels*
A. Bot, F.P. Duval, and, W.G. Bouwman
Food Hydrocolloids **21** 844–854 (2007)
- *On characterization of anisotropic plant protein structures*
G.A. Krintiras, J. Göbel, W.G. Bouwman, A.J. van der Goot and G.D. Stefanidis
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- *Small angle neutron scattering quantifies the hierarchical structure in fibrous calcium caseinate*
B.Tian, Z. Wang, L. de Campo, E.P. Gilbert, R.M. Dalgliesh, E. Velichko, A.J. van der Goot, W.G. Bouwman
Submitted for publication (2020)
- *Fibre formation in calcium caseinate influenced by solvent isotope effect and drying method – A neutron spectroscopy study*
B.Tian, V. Garcia Sakai, C.P. Pappas, A.J. van der Goot, W.G. Bouwman
Chemical Engineering Science **207** 1270-1277 (2019)
- *Impact of water degumming and enzymatic degumming on gum mesostructure formation in crude soybean oil*
T. Nikolaeva, T. Rietkerk, A. Sein, R. Dalgliesh, W.G. Bouwman, E. Velichko, B.Tian, H. van As, J. van Duynhoven
Food Chemistry **311** 126017 (2020)