Food structure from the inside with neutron scattering

- Neutrons
- Small angle neutron scattering (SANS)
- Spin-echo small-angle neutron scattering (SESANS)
- Margarine
- Milk, yoghurt
- Tuneable colloids
- Water holding proteins
- Plant protein meat
Why neutrons for food?

- no electric charge - penetrates deep into specimen (easy sample environment)

- Interaction element and isotopic sensitive
  - contrast variation

- has a magnetic moment
  - magnetic fields to detect path
Contrast matching to make parts structure (in)visible

Morna Fisken, Britlab
https://youtu.be/OZxtw1c3ieM
Small angle scattering (neutrons, X-rays or light same same principle)

Brian Pauw
https://youtu.be/n-8Y2p4kN4M
The phytosterol compounds structure oils without solid fats

\[
\begin{align*}
\gamma\text{-oryzanol} & \\
\beta\text{-sitosterol} & 
\end{align*}
\]

A. Bot (Unilever), et al. Faraday Discuss. 158, 223-238 (2012)
β-sitosterol and γ-oryzanol in d-decane

$10^{-2}$ $10^{-1}$ $10^{0}$ $10^{1}$ $10^{2}$ $10^{3}$ $10^{4}$

$I \text{ [cm}^{-1}\text{]}$

$Q \text{ [Å}^{-1}\text{]}$

2.0 nm

7.8 nm

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Double walled helical ribbon

$\rho_2$, $\rho_1$, $\rho_{\text{solv}}$

$r_{\text{solv}}$, $r_1$, $r_2$

$0.8 \text{ nm}$, $7.2 \text{ nm}$, $9.5 \text{ nm}$, $2.3 \text{ nm}$
**SANS vs SESANS**

- **Sensitivity:**
  - 1 nm – 500 nm
  - 30 nm – 20 µm

- **Length instrument:**
  - 12 – 80 m
  - 5 m

- **Reciprocal space**
  - Real space
SESANS = Fourier transform scattering \Rightarrow \text{projected density correlation function}

Sterically stabilised silica particles $d=298$ nm in deuterated cyclohexane $\phi_v=0.05$
Casein micelle in milk polydisperse: 50 - 200 nm

Structure determined of dairy products

Hans Tromp
NIZO food research
the Netherlands
SESANS measures size distribution of milk (casein micelles)

Size distribution is visible in measurements
Log-normal distribution

Spin echo length [nm] vs. P/P₀

Radius [nm] vs. size dist. [nm⁻¹]

SESANS
sedimentation field flow
From milk to yogurt and curd

Depletion interactions in charged, aqueous colloid-polymer mixtures (model for e.g. milk)

- Salt reduces repulsion
- Polymers give attraction

polymer depletion zone

Kitty van Gruijthuijsen, Peter Schurtenberger, Anna Stradner - Lund University
Adolphe Merkle Institute, Université de Fribourg
Colloids

\[ \ln P(z)/t \]

- 32 wt% in 2mM
- 26 wt% in 1.5mM
- 26 wt% in 3mM
- 20 wt% in 50mM

Attractions

\[ \phi \]

\[ \text{C} \]

Repulsions

\[ [\text{NaCl}] \]

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Gels

\[ \ln \frac{P(z)}{t} \]

-1000 -900 -800 -700 -600 -500 -400 -300 -200 -100 0 0.5 1 1.5 2 2.5 3

\[ z [\mu m] \]

Attractions
\[ \phi \]
spheres

\[ [NaCl] \]

TuDelft

In 1.5 mM

In 50 mM
Water holding of ovalbumin gels
Juiciness, release tastants

Maaike Nieuwland, TNO & TI Food and Nutrition
Acid reduces water holding
Vegetarian steak
Mechanism of fibre formation of sheared plant proteins?

George Krintiras
Neutron refraction: $\#$ layers + orientation

$36 \pm 4$ layers / 5 mm

$\pm 35^\circ$ orientation
Food and neutrons are a tasty combination

- Bulk
- Texture micrometre
- Quantitative
- In principle in-situ
- Interaction
- Aggregation
- Water holding
- Alignment

Wim G. Bouwman
Acknowledgements

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*Direct comparison of SESANS and SAXS to measure colloidal interactions*, K. van Gruijthuijsen, W.G. Bouwman, P. Schurtenberger and A. Stradner, EPL **106** 28002 (2014)

