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Invited lecturers:

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Microscopy techniques and structure dynamics in foods

Johan Mattsson (University of Leeds UK) k.j.l.mattsson@leeds.ac.uk
The use of light scattering in food-related soft matter

Peter Fischer (ETH Zurich Switzerland) peter.fischer@hest.ethz.ch
Rheology of gels: Manoeuvring in the low viscosity - high elasticity corner

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Fluid interfaces in multiphase food systems: Structure, functionality and characterisation techniques

Microscopy techniques and structure dynamics in foods

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The microstructures at different length-scales are very important for the properties and functionality of foods. Several techniques are required to image the microstructure at different length-scales dependeing on the physical conditions of the food. In this talk, different examples on the coupling between microstructure and properties will be given. In addition, the principles, advantages and limitations of some powerful microscopy techniques useful for foods will be presented.

Two different aspects of structure dynamics will be discussed in this talk. They involve building up of structures as well as dynamics in terms of molecular diffusion. Diffusion is vital for many food properties such as water management in pasta and pastry products, oil migration induced fat bloom in chocolate and oral taste release. These examples show that it is important to have good control over the diffusion properties to obtain desired functionality. Therefore, thorough understanding of structure - mass transport relationships at different length scales in the structure and good measurement techniques for global and local for diffusion are essential. In this talk, the coupling between structure and diffusion[1] at different length scales in Foods and soft porous heterogeneous materials will be discussed.

Quantitative confocal microscopy allows for simultaneous determination of the detailed microstructure at micrometer level and local quantitative information regarding mass transport, electrostatic interactions, rheological properties etc. A brief overview of different microscopy-based techniques to characterize local diffusion will be given in this presentation. Confocal laser scanning microscopy (CLSM) in combination with Flourescence recovery after photobleaching (FRAP)[1] or raster image correlation spectroscopy (RICS) are versatile methods to determine quantitative diffusion properties locally directly in the microscope. They can be used in many types of soft porous homogeneous and heterogeneous foods and biomaterials. A new powerful FRAP technique that gives precise measurements on the local diffusion coefficient will be presented[2]. In addition, determination of the interplay between flow and diffusion using microscopy, FRAP and RICS[3] will be presented.

Food properties change as a function of time and surrounding conditions. CLSM-FRAP combined with different stages to control surrounding conditions is powerful to monitor kinetics. Here, results on microstructure and probe diffusion in phase separated biopolymer mixtures determined by FRAP and NMR diffusometry will be presented[4]. The effect of the characteristic wavelength and the equilibrium concentration on the diffusion in bicontinuous phase separated biopolymer mixtures will be demonstrated using quantitative microscopy and Lattice-Boltzmann simultations. In addition, the effect of confinement on the phase separation kinetics will be discussed[5]. Results that reveal the effects of charge density, size and concentration on diffusion of negative probes in positively charged β-lactoglobulin gels will be presented[6].

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Fluid interfaces in multiphase food systems: Structure, functionality and characterisation techniques

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Many food products contain two or more immiscible gas or liquid phases, with one or more phases dispersed in another as bubbles or droplets, forming foams (e.g., coffee foam), emulsions (e.g., mayonnaise, dressings, dairy drinks) or aerated emulsions (e.g., ice cream). An important feature of these systems is the large interfacial area that exists between the different phases, up to several m^2 per millilitre of dispersed phase. This fluid interface has to be physically stabilised with emulsifiers, which facilitate the break-up of droplets (or bubbles) during homogenisation, and contribute to the metastability of the systems post-homogenisation, by preventing coalescence. For food applications, two main categories of emulsifiers exist: Low molecular weight emulsifiers (LMWEs), and amphiphilic biopolymers, the latter category being mostly represented by proteins. Recently, interest has also been rising in using biobased particles with dual wettability instead of conventional emulsifiers, which can stabilise foams or emulsions through a Pickering mechanism [1].

A number of challenges may be encountered when attempting to design food dispersions with controlled properties. A first, obvious one, is to prevent the rapid physical destabilisation of the systems (e.g., flocculation, coalescence) which leads to unacceptable aspect and texture. A second one is to ensure the chemical stability of the systems; many food emulsions contain chemically labile molecules (e.g., polyunsaturated lipids, vitamins, phytochemicals), which can be damaged by oxidative reactions, leading to a deterioration of the sensory and nutritional quality. A third one is to control the digestive fate of emulsions, for example, to delay digestion such that satiety feelings are enhanced [2]. Interestingly, all of these challenges are related to the properties of the interfacial layer. It is thus of utmost importance to control the composition and structure of fluid interfaces in multiphase food systems.

Such a control is, however, intrinsically difficult. First, most food systems have a complex composition, including many surface-active molecules, that partition between the available phases and may compete for adsorption at the interface. Often, the amount of emulsifiers used is much higher compared to what is strictly needed for complete interface coverage, which implies that a large excess of non-adsorbed emulsifiers remains in the continuous phase; and that the overall composition of surface-active species does not necessarily reflect the composition of the interface. Second, the interfacial composition may evolve in time, with, e.g., interfacial protein polymerisation, or adsorption of chemical degradation products. And in addition, even when one is able to determine the composition of the interface, its structure still has to be unravelled, which may include lateral phase-separated domains, aggregates, multilayers, etc.

It is thus necessary to determine the composition and structure of fluid interfaces in multiphase food systems, which can be achieved through different approaches [3]: (i) in real systems (e.g., emulsions), with non-destructive methods; this refers mostly to a range of microscopy or spectroscopy techniques; (ii) in real systems, after phase separation (e.g., separation of the cream and aqueous phases of emulsions, followed by analysis of the separate phases); (iii) in model dispersions, e.g., foams or emulsions produced with microfluidics, which allows for high control of the production conditions, and investigation of interface stabilisation at short time scales; and (iv) on model, two-dimensional interfaces (air-water or oil-water), which allows for measurement of e.g., the rheology of the formed layers, their thickness, or their topography. Combining different approaches is needed to obtain a comprehensive description of such complex fluid interfaces, which can, in turn, help designing multiphase food systems with controlled properties.

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The use of light scattering in food-related soft matter

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Light scattering techniques are excellent tools to study both structure and dynamics in soft materials. For food systems, which are often characterised by complex structures and a broad range of motions both of molecular, supramolecular or colloidal structures, light scattering can be particularly useful for understanding the systems. Moreover, light scattering techniques can be used to characterise the rheological properties of soft matter and this can be particularly useful in systems that are sensitive to standard rheological testing.

In this presentation, I will provide an overview of how different light scattering techniques and approaches can be used to characterise the state of a particular soft material as well as the transition between different states. Important examples will include complex fluid mixtures, polymer solutions, polyelectrolytes, gels and glasses, both where the key building blocks are molecular, supramolecular or colloidal.

Rheology of gels:
Manoeuvring in the low viscosity - high elasticity corner

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Gelation, although commonly utilized in the design and production of food may issue several experimental challenges to the rheologist. The transformation from a liquid to a solid response asks for a wide sensitivity range of the rheometer, while slip due to syneresis compromise the data, shear deformation change the gel structure for good or bad, or gel fracture might terminate the rheological experiment instantaneously. But what, if the gel undoubtfully can be seen, touched, and deformed but the rheological data are not sophisticated at all? [1] Using two mucus-based systems, hagfish slime and sputum from cystic fibrosis patients, the rheology of low viscous but highly elastic materials will be discussed [2, 3]. The high water holding capacity of mucin generates a dilute viscous gel and simultaneously provides a widely spanning network structure introducing the elasticity to the sample. In Figure 1 the influence of sample, electrical, and inertia torque are discussed as one of the limiting factors in oscillatory measurements. Similar problems such as slip layer formation, rheometer sensitivity and inhomogeneous sample structure are discussed for hagfish slime, which is composed from mucus and long intermediate filaments. In a final step, the use of elongational measurements will be discussed as option for samples unsuitable for rotational or oscillatory experiments.

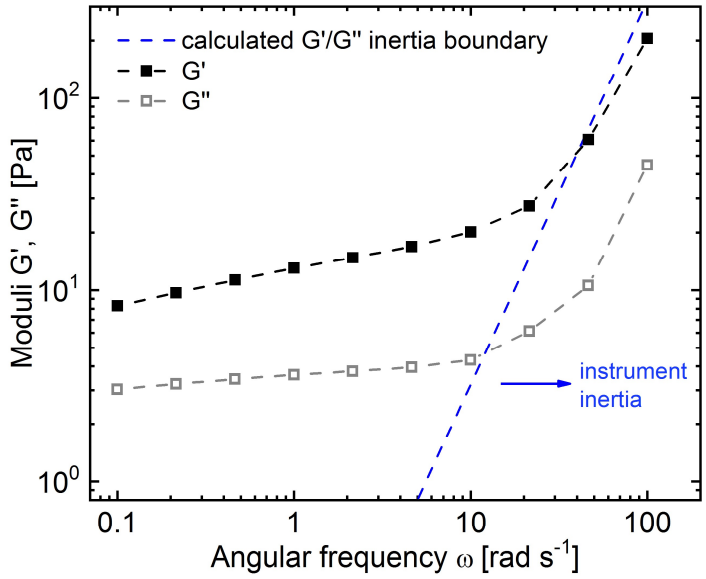

Figure 1: Rheology of cystic fibrosis sputum. Frequency sweeps depicting G' (storage modulus and G" (loss modulus). The blue dashed line indicates the calculated instrument inertia limit (taken from [2]).

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