Workshop on Synchrotron X-ray and Neutron application to Food Science and Technology

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Book of Abstracts

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Synchrotron SAXS and SANS Reveal the Formation of Functional Nanostructures during Food Digestion

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The combination of in situ time-resolved small angle X-ray- and neutron scattering combined with cryogenic transmission electron microscopy can provide unique insights into transient soft nanostructures during food digestion and processing.
In this presentation, the discovery of highly ordered geometric nanostructures during the in vitro digestion of food emulsions such as milk and mayonnaise under simulated in vivo conditions will be discussed: Transitions from normal emulsion through a variety of differently ordered structures were observed. The colloidal structure formation and transformation may play a vital role in the delivery of the lipid-soluble bioactive food molecules such as hydrophobic vitamins, carotenoids and lipids to the circulatory system of the body [1,2,3]. Selective deuteration of lipids and solvent contrast variation was applied to map the location of molecules in the complex multicomponent nanostructures [4]. Based on these findings, we demonstrate the design of functional delivery systems for poorly water-soluble antimicrobial peptides, a promising alternative to conventional antibiotics. These peptide nanocarriers also protects the sensitive molecule from degradation and boost its antibacterial activity [5].
The results shed light on the formation and transformation of functional bio-nanostructures with the aim of designing biomimetic delivery systems for hydrophobic functional molecules.

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Seeing Through Food - New X-ray Imaging Modalities in Food Science

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Applications of X-ray imaging within food science has previously been limited by the poor contrast in conventional X-ray absorption. However, this has changed with the advent of phase-contrast and dark-field imaging.

Due to the increased sensitivity towards small variations in electron density in soft matter materials, phase-contrast imaging have demonstrated improved signal-to-noise ratios (SNR) as well as contrast-to-noise ratios (CNR) for various food products such as meat [1]. Furthermore by recording the USAXS signal, dark-field imaging provides a sensitivity to ordered micro-structures which has been successfully applied in e.g. detecting foreign bodies in food products [2].

Here we present examples of applications of these novel modalities:

- X-ray phase-contrast imaging was applied to study heat-induced changes in electron density in protein structures in meat [3]. The phase-contrast modality provided an image contrast between protein, connective tissue, water and fat phases which allowed a quantification of parameters such as the cooking loss.
- X-ray dark-field imaging was used to distinguish between raw, frozen and defrosted fruits and berries [4]. When freezing and defrosting the food products, changes in the microstructures such as the pore space provide a contrast in the X-ray dark-field modality.

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Summary:

With the advent of X-ray phase-contrast and X-ray dark-field imaging, novel applications for X-ray imaging within food science have become available.

Phase-contrast imaging provides an increased sensitivity towards electron density differences in soft matter materials such that contrast between even small mass density differences is possible. In dark-field imaging the USAXS signal is recorded which provides a sensitivity to ordered micro-structures such as fiber or grain structures.

Here we present examples of applications of using X-ray phase-contrast imaging to study changes in electron density in protein structures in meat upon heating and applying X-ray dark-field imaging to distinguish between raw, frozen and defrosted food products.

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Introduction to the use of large-scale facilities for food science and technology

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Large scale facilities, in particular synchrotron x-ray sources and neutron source, provide a variety of tools for structural and chemical characterisation.

The range of methods available for atomic to millimetre scale characterisation of food and food related materials will be presented. The complementarity of x-ray and neutron methods will be discussed and some examples of existing applications will be shown.

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Self-assembly in food systems

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The increasing importance of health & wellbeing from a healthcare system perspective urges Food Industry to speed up their research and development work of new innovative products, which allow the consumers to better sustain or promote their personal health and wellbeing. Other key market trends are pleasure, convenience, naturalness of the food, or appealing taste and aroma.

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Small-angle scattering study on the lecithin stabilizer layer structure in tetracosane-water nanoemulsions and -suspensions

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The interfacial stabilizer layer in lipid emulsions and suspensions controls the lipid oxidation of encapsulated bioactive compounds and the crystallization of the nanoemulsions. As a model system tetracosane (C24 alkane, TCS) nanodispersions stabilized by the lecithin 1,2-dimyristoyl-sn-glycero-3-phosphocholine (DMPC) was considered here. The emulsion droplets (about 65 nm in diameter, as measured by photon correlation spectroscopy) exhibit a strong super-cooling (ΔT about 20 K) and crystallize in an for TCS unusual orthorhombic crystal structure (space group Pca21 as verified by wide-angle x-ray scattering).

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Understanding and Improving Sustainable Water Purification Processes that use seeds from Moringa Trees

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Pure water is essential for good health. It is necessary for food preparation and sanitation. Supply of water is still a major challenge and technology that can be used without specialist support in remote and rural areas is still needed in many countries. An extract from the seeds of the Moringa oleifera tree that is principally a low molecular mass protein is known to be efficient as a coagulating agent for water purification.

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SELF-ASSEMBLIES BASED ON THE NEW OMEGA-3 LIPID EICOSAPENTAENOIC ACID MONOGLYCERIDE

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ω-3 PUFA supplements are not only available in free fatty acid, triglyceride, ethyl ester, and phospholipid-enriched forms but they are also available in the form of monoglycerides (monoacylglycerols): eicosapentaenoic acid (MAG-EPA), docosahexaenoic acid (MAG-DHA), and docosapentaenoic acid (MAG-DPA) monoglycerides, respectively. Recent studies demonstrated the potential therapeutic use of these newly synthesized omega-3 (ω-3) polyunsaturated fatty acid (PUFA) monoglycerides owing to their beneficial health effects in various disorders including cancer and inflammation diseases.

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Building a research infrastructure for food, nutrition & health

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Building a research infrastructure for food, nutrition & health –
what can the Richfields/FNHRI initiative learn from the Synchrotron X-ray and Neutron facility?

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Insight into casein as studied by X-ray and neutron scattering

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The colloidal structure of casein micelles is of crucial importance for the use of milk in food products. Casein makes up the majority of protein in milk (about 80% for cow's milk), and in pure milk the casein is assembled into so-called casein micelles. The casein micelles are spherical particles with a size of hundreds of nanometers and with an internal structure that is not completely understood.

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The need for advanced characterization tools in food processing and packaging industry

Author: Mats Qvarford[1]

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In development and quality assurance reliable material analysis and characterization methods are of prime importance.
Lately more advanced virtual engineering methods calls for more advanced material characterization to have the adequate input parameters.
This and the possibilities to have in situ and dynamic processes studied at ESS and MAX IV make these facilities very interesting for the food processing and packaging industry.

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Crystallography in food science: the case story of chymosin

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Enzymes are proteins that catalyze biological processes, they are essential for biological function and life.
In food sciences enzymes can play many different roles either in the degradation/transformation of natural food products or in the synthesis of new products. Previously most enzymes used in the food industry were obtained by natural sources, but the development of advanced biotechnological methods to produce recombinant proteins gives new opportunities for the changing/ improving enzyme function.
X-ray crystallography can provide structural information to atomic resolution on a crystalline compound, and since function is intimately linked to structure, X-ray crystallography serves as a prime tool in enzymology.

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Imaging the structure of bread

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Product Design and Perception at RISE Agrifood and Bioscience has long experience of characterization and evaluation of microstructures at different length-scales in relation to material properties and functionality. Different microscopy techniques are available for soft materials such as light microscopy (LM), confocal laser scanning microscopy (CLSM) and electron microscopy (TEM) and advanced sample preparation at RISE Agrifood and Bioscience. Microstructural characterization of materials is a key factor in the understanding of material behavior and properties. The collaboration with SOFT Microscopy Centre at Chalmers and MAX IV in Lund also offers further unique possibilities for advanced studies of microstructures.

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Neutron imaging: from meat cooking to protein hydration

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The food scientist is commonly confronted with the challenge of modifying the formulation of a food product. The objective may be to enhance the taste, texture or appearance of the food, to produce a product with a longer shelf-life or a healthier image, or to improve manufacturing efficiency by incorporating a cheaper ingredient or adopting a new processing technology. The speed with which these objectives can be accomplished depends on the level of fundamental understanding that exists on the key physico-chemical factors affecting products properties. In the case of foods proteins, it is especially important to understand how the interfacial and aggregation behaviour of the proteins are affected by processing conditions (heat, drying, freezing, shear forces), or by molecular interactions with other constituents (fat, hydrocolloids, aroma, water⋯). One of our goals is to improve insights into such factors by taking advantage of polymer science concepts and neutron scattering technique applications to such systems, to the systematic study of model food proteins or food ingredients.

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X-ray grating-based imaging of food - from synchrotrons to production lines

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In the last decade, X-ray imaging using a grating-interferometer (XGI) has evolved from synchrotron research to commercially available lab equipment. Besides the conventional attenuation-based contrast, XGI offers the complementary phase-contrast and dark-field modalities. As these are especially sensitive towards soft-tissue samples, applications within food science have long received interest particularly using the X-ray dark-field modality. As the latter is sensitive to X-ray scattering in the USAXS regime, structures on the micron-scale can be investigated. This makes it applicable for many food science studies.

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Ptychographic X-ray computed tomography of extended colloidal networks in food emulsions

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Texture, mouthfeel and rheology of food are related to the underlying food structure. Microscopy is the work horse in deducing food structure. The understanding and prediction of texture, mouthfeel and rheology is hampered by the lack of suitable non-destructive 3D imaging techniques with submicron resolution. We present results of quantitative ptychographic X-ray computed tomography applied to a palm kernel oil based oil-in-water emulsion. The measurements were carried out at ambient pressure and temperature. The 3D structure of the extended colloidal network of fat globules was obtained with a resolution of around 300 nm. Through image analysis of the network structure, the fat globule size distribution was computed and compared to previous findings. In further support, the reconstructed electron density values were within 4% of reference values.