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Water and Structure Management

Chairs: Anne-Marie Hermansson and Lilia Ahrné

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Water, Structural Changes and Food Appearance

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The appearance of a food is one of the most important factors defining consumer acceptance. During food processing several steps change the physical structure of the matrix. At the same time, brown polymers are generated by caramelization and Maillard reactions. The result of complex interactions of incident light with the food matrix affect appearance attributes, such as transparency, translucency, gloss, lightness and chromatic perceptions. The objective of the present work was to study the effect of water on the physical, microstructural and chromatic changes affecting appearance attributes during food processing. Samples at different process stages of corn-flakes production were selected to illustrate the effect of water and temperature on the destruction or generation of interfaces that affect the way in which light interact with the solid matrix. Thermal properties of the material were determined by DSC and a temperature/composition phase/state diagram was constructed. Water mobility was studied by ^{1}H-NMR at the different stages. Surface color was affected not only by pigment development but also by microstructural changes. The refractive index difference among the different phases of a non-homogeneous food caused light dispersion and therefore appearance and visual texture changes. An integral approach that takes into account color, pigment concentration as well as microstructural and physical changes is important in order to understand visual color perception of foods. The changes promoted in the raw matter may be characterized by means of phase phase/state diagrams, which, combined with the molecular mobility studies may help to define process design variables or to develop innovative foods.

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Water in Food, Equilibria versus Dynamics.

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Throughout its existence, ISOPOW has continually focused on the developing understanding of water in foodstuffs, from dry biscuits to gelled systems. This covers a range of water contents from less than 1% to greater than 99%.
One of the first recommendations was that water activity rather than water content was a better predictor of material properties and microbiological stability. At the same time, techniques which allowed the molecular dynamics of water were improving, and became applicable to real foods. Resolution between the approaches involved extensive debates of "monolayer absorption" and "bound water". More recently, the identification of "glassy states" in foods, and the role of water as the ubiquitous plasticizer has added another dimension to our concepts.
Can all these approaches be integrated into a common understanding of the role and behaviour of water in foods?
As a first step, we have attempted to resolve the surprising success of water activity, glass transitions and molecular mobility studies in predicting the stability of food. We have examined two particular problems, where comparisons can be made by the use of appropriate techniques.

The first relates to the phenomenon of hysteresis in drying and rehydration.
By a combination of pseudo equilibrium measurement of adsorption and desorption, together with rapid sampling by Differential scanning calorimetry, we have shown that the form of the absorption and desorption isotherms relates to glass formation, whilst the ageing of glasses, facilitated by mobile water, is the probable cause of hysteresis.

The second example relates to the growth of microorganisms, where the presence of structured gel states apparently act as an additional growth inhibitor, not related to Aw. Here we have shown by analysis of proton NMR studies, that the effect can be related to long range translational diffusion rates of water.

With these results in mind, we propose that the really vital properties of water are its own mobility, and its capability to facilitate solute diffusion. The success of Aw predictions are because this simple measurement correlates well with both of these properties, across a very wide range of water content.

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(1) **Champion, D., Loupiac, C., Simatos, D., Lillford, P.J. and Cayot, P.** 2011. Structural Relaxation during the Drying and Rehydration of Food Materials-the Water Effect and the Origin of Hysteresis. Food Biophysics, **6**, 160-169

(2)**Huang, Y., B. Chapman, M. Wilson, and A. D. Hocking**. 2009. Effect of Agar Concentration on the Matrix Potential of Glycerol Agar Media and the Germination and Growth of Xerophilic and Non-Xerophilic Fungi. International Journal of Food Microbiology **133**:179-185.

(3)**Davies, E., Huang, Y., Harper, J.M., Thomas, D.S., Burger, I.M. and Lillford, P.J.** 2010. Dynamics of water in agar gels, studied by low and high resolution NMR spectroscopy. International Journal of Food Science and Technology, **45**:2502-2507

Structure design for diffusion and flow properties

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A main focus of structure design of foods, pharmaceuticals, hygiene products and other soft biomaterials is to master inherent structural properties of supramolecular biomaterials to control properties and tailor specific functions. Properties related to rheology and mass transport are crucial for a wide range of applications such as controlled release, barrier properties, swelling and dissolution, water binding as well as the sensory perception of food during consumption and release of nutrients during degradation in the body.

The toolbox for microstructure characterization include a range of microscopically techniques that can cover length scales from nanometers to micrometers, but we also need to understand the dynamics of structure formation and breakdown to fully understand how to tailor-make processes and conditions that give the desired characteristics of the product. Local events can have a dramatic effect on the overall properties. New techniques are available for measurement of properties such as local diffusion properties in complex structures. We also know more about the effect of structure complexity such as confinement effects in complex multiphase systems. Very interesting developments are taken place where experimental data on the micrometer and nanometer scale can be directly used to simulate flow and diffusion.

Water in food refrigeration

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In food refrigeration technique, behavior or physical properties of water plays an important role to control the quality of frozen food. On freezing process, instead of quick freezing as common method to make smaller ice crystals in food, recently an innovative freezing technique using supercooling has attracted. However, the supercooling phenomena in aqueous solution or cell tissue cannot be controlled yet. During transportation or storage of frozen food, ice of food surface and week bonded water in food sublimes, and also recrystallization of ice particles progresses in food, which are subject to activity and diffusion of water under subzero temperature. This presentation will focus on the following topics: 1) Factors affecting for supercooling from aqueous solution, 2) Membrane damage in frozen vegetable due to ice segregation phenomena caused by a local ice nucleation in tissue, 3) Anomalous water diffusion in concentrated solution, 4) Prediction of sublimation from frozen food considering water activity under low temperature, 5) Recrystallization of ice, and so on.

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