



Topical Research Meeting on Physics in Food Manufacturing

Session: Sensing, Imaging and Monitoring

Continuous fluid processing systems using reverse flow cyclones with closed-loop control

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Fluidics processes such as mixing of fluids and manufacturing of microcapsules are a key aspect of food processing and manufacturing, and many related processes are performed traditionally in batches. This can lead to limitations in continuous production environments arising from inflexibility and difficulties in control. Significant improvements in process control and reliability could clearly result from adoption of a continuous approach.

Complex fluid dynamics systems can be configured to engineer the interaction between multiple ingredients, and we will present one such system approach based on the use of reverse cyclone mixing chambers for applications including creation of emulsions or microcapsules and potentially the mixing of fluids of widely-differing viscosities. A key aspect is the incorporation of continuous process monitoring (e.g. monitoring of oil/water ratio (based on RF techniques) and/or microcapsule diameter (using optical approaches)) and feedback as the basis of closed-loop control. In our presentation we will describe the basis of operation of the reverse cyclone fluids process, the applicable sensing technologies and the opportunities for the use of these as part of a control loop to optimise and tune the process 'on the fly'.



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The role of the EPSRC Centre for Innovative Manufacturing in Food in delivering next generation technologies to meet the future needs of the Food Industry

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The EPSRC Centre for Innovative Manufacturing in Food is charged with creating a National centre approach to innovative and blue skies research to serve the needs of the future food manufacturing industry. To that end £5.6m research funding has worked on two Grand Challenges (Innovative materials, products and processes and 2) Sustainable food supply and manufacture) and six associated research themes (New processing technologies, Upgrading of ingredients for improved resource utilisation, Food manufacturing for healthy diets, New flexible manufacturing processes, Eco-Food manufacturing, Sustainable Food Supply Chain).

Work will be presented on progress to date in each of these areas relevant to Physics challenges.



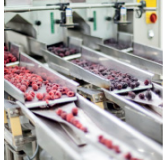
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Tribology and oral processing: Mechanical degradation and friction of semi-solid foods in a simulated tongue-palate contact

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The perception of many food attributes is related to mechanical stimulation and friction experienced in the tongue-palate contact during mastication. Friction in the tongue-palate is determined by the changing film properties (composition, component distribution, thickness) in the conjunction as the food is masticated. One of the current challenge in food tribology is to develop relevant bench tests linking measured friction and mouth feel. The talk reports a new test to follow the evolution of friction in a simulated tongue-palate contact as food is mechanically degraded by rubbing. The tongue-palate contact was simulated by a PDMS ball (tongue model) which loaded and rubbed against a glass surface (palate model). Friction was recorded over 30 seconds of rubbing for a range of dairy and chocolate products. Clear distinctions are observed in the friction-time curves for different fat-content dairy products and chocolate compositions. The method also allows post-test visualisation of the rubbed film on the glass slide which provides insights into the mechanisms of food breakdown and component loss and this can be linked to the friction profiles.



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The flow and evolution of ice-sucrose crystal mushes

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Ice crystals, as a suspension in an unfrozen sugar syrup, are an important component of ice-creams and sorbets. These evolve over storage and must flow during production and consumption. Ice mushes also occur widely in engineering applications and in nature, for example in refrigerant systems, sea ice and cryovolcanoes. The physics of food therefore provides a model system for understanding a much broader class of materials and phenomena. Here we measure the thixotropic rheology and crystal size evolution of an ice suspension in a Newtonian sucrose solution. We are able to relate the power laws that result to the physics of cluster formation, sintering and breakup. We also find an unexpected scaling for the ripening behaviour of the crystals over long periods of time under shear.



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An insight into fibre formation mechanisms through computer simulation

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Fibres formed by spontaneous self-assembly of small molecules, such as peptides, are key components of many foods: providing texture, stabilising formulations and influencing flow and processing properties. Also, naturally occurring “fibre” is central to a healthy diet, reducing the likelihood of diseases such as heart disease and diabetes, and generally improving digestive health. There are also various other situations in which spontaneously formed fibres can play either a favourable or an unfavourable role. Gels and some diseases, such as Alzheimer's disease, are examples from the two ends of this spectrum of fibre-related phenomena.

Whilst fibre formation is clearly ubiquitous, its microscopic origins and control mechanisms are not well understood. Here, therefore, we use Molecular Dynamics simulation of coarse-grained disc-shape particles to study the spontaneous initiation and growth of fibre structures from an amorphous solution. The effects of different parameters on the temperature-dependent process of fibre self-assembly are, thus, investigated. Through this, a pathway for the hierarchical formation of fibres is identified. Developing this understanding further, it is observed that adding small seeds into the system can induce fibre self-assembly at significantly higher temperatures. By shedding light on the mechanisms of self-assembly of fibres, this study provides useful insights for improved control of fibre-containing foods which should be of benefit to future process or product development.



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Statistical thermodynamics of food from first principles: application to biomolecular stability, gelation and flavouring

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Profound changes take place in biomolecular gelation, denaturation and aggregation, as well as solubilisation that take place when we add the third component to the aqueous solution [1-3]. The third component (referred to as cosolvent) has been used widely in food as gel stabilizers or flavour solubilizers, and have acquired confusingly diverse terminologies, such as osmolytes, hydrotropes, cosolutes and denaturants [4-6]. Beneath the diversity of terminologies and phenomena, we have shown that there is a universal mechanism at work of cosolvent action [1-6]. Cosolvent-biomolecule interactions are often weak and non-specific, and have therefore eluded the traditional chemical approach through stoichiometric binding [1,2,7]. Based upon a rigorous statistical thermodynamic approach, we have successfully established a way to characterize such weak, nonspecific interaction [1,2,7] at work in food, and have successfully applied our theory to clarify the molecular-based mechanisms of the role of sugars on the gelation of gelatin, agarose [3], carrageenan [5] and tofu [7], as well as some of the molecular interactions present in caffeinated beverages [4].

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- [5] Stenner, Matubayasi & Shimizu, **Food Hydrocolloids**, 54, 284 (2016).
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- [7] Shimizu, Stenner & Matubayasi, **Food Hydrocolloids**, 62, 128 (2017).



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Modelling the emergent flow behaviour of emulsions

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Emulsions are found throughout various food products, including mayonnaise, milk, and beer; hence knowledge of how they flow is valuable. These non-Newtonian fluids and their properties impact every stage of the food product life cycle, from efficiency in design and manufacture to taste and texture in consumption.

The rheology of emulsions depends upon many factors including the droplet concentration, surface tension, viscosity ratio, and shear rate. Approximate theoretical and empirical models exist to describe some of these effects, but these are limited in applicability. Investigations into these factors have been undertaken, using a newly developed meso-scale computational model solving the droplet physics allowing for the prediction, evaluation and creation of macroscale models incorporating the mentioned factors.