

# Food Physics 2026

4–5 February 2026

Arla House, Leeds, UK



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## Programme

### Wednesday 4 February

08:30 Registration

09:00 Welcome and Introduction

**Peter Schuetz**, Unilever and **Tom Grinyer**, CEO, Institute of Physics

Session A: Modelling of Food Structure and Processing (Part I)

Chair: **Gleb Yakubov**, University of Leeds

09:20 (Invited) Insights into wheat milling and breadmaking: A few of my favourite things

**Grant Campbell**, University of Huddersfield

10:20 Solute Exclusion as the Basis for Periodic Ice Structures in Directional Freezing

**Yuechuan Lin**, Adolphe Merkle Institute, University of Fribourg

10:45 Coffee Break

Session A: Modelling of Food Structure and Processing (Part II)

11:15 Sugar-Fat Substituted Icings: Plausible possibility or just a piping dream?

**Peter Cooper**, University of Sheffield

11:35 Processing of food powders: from microscopic interactions to macroscopic powder bulk behavior

**Roozbeh Valadian**, Granutools

12:00 Benefits of IOP Membership

**Allie Vickers**, Institute of Physics

12:10 Flash Posters

12:30 Networking, Lunch and Posters

13:50 Sponsored Talk:

**Banu Sezer**, Anton Paar

Session B: Physics and Measurement for Future Food Systems and Processing (Part I)

Chair: **John Bows**, PepsiCo

14:00 (Invited) Ten years of Food Physics

**Megan Povey**, University of Leeds

14:50 Elemental and Microstructural Composition of Instant Pounded Yam Flour Evaluated by Energy Dispersive X-Ray Spectroscopy in a Scanning Electron Microscope System

**Ekpereka Anajekwu**, University of Surrey

15:10 Tea Break

Session B: Physics and Measurement for Future Food Systems and Processing (Part II)

- 15:50 (Invited) Who/what is food physics for?  
**Wilson Poon**, University of Edinburgh
- 16:40 Multi-functional structuring behaviour of jellyfish biomatrices  
**Mie Pedersen**, University of Southern Denmark
- 17:05 End of Session / Networking
- 17:30 Coach to Oulton Hall / Free Time
- 19:00 Conference Dinner  
After Dinner Speaker: Peter Barham

Thursday 5 February

Session C: Food Colloids and Molecular Assemblies

Chair: **Peter Schuetz**, Unilever

- 08:30 (Invited) Colloidal Particles and Droplets in Granular Dispersions: Modulating Grain Interactions, Sintering and Flowability  
**Krassimir Velikov**, Unilever
- 09:20 Multiscale Insights into Chocolate and Compound Matrices: Linking Refining Technology, Particle Size, and Fat Content to Rheological and Lubricating Behaviors  
**Clémence Gallery**, Cargill France SAS
- 09:45 Soluble Amylose Chains Inhibit Gelatinisation and Retrogradation in Waxy Corn Starch  
**Gleb Yakubov**, University of Leeds
- 10:05 Stretch, Aim, Shoot! Probing Polymer Network Structure During Elongational Flow Using Synchrotron CaBER-SAXS: In Pursuit of Improved Texture of Alternative Meat  
**Lathika Vaniyan**, University of Nottingham
- 10:25 Coffee Break
- 10:55 Panel Discussion: The future of food science training and the impact on industry  
Hosted by Gleb Yakubov, University of Leeds
- 11:55 Networking, Lunch and Posters

Session D: Soft Matter Physics: interfacial Phenomena, Foams & Emulsions & Rheology

Chair: **Megan Povey**, University of Leeds

13:20 A kinetic model fitting approach to quantify water mobility in mycoprotein paste using osmotic dehydration

**Rosa Selene Espiricueta Candelaria**, University of Nottingham

13:40 Multi Speckle – Diffusing Wave Spectroscopy – an accurate tool to study structural properties of dairy products

**Roland Ramsch**, Speclz

14:05 Shear induced structure formation of protein microparticles

**Maïke Segers**, University of Amsterdam

14:25 Tea Break

14:45 Award of ECR Prizes

15:00 Closing Remarks

15:25 End of Conference

## Poster Programme

- P1 Biomimetic Modelling of Oral Mucus Microstructure for Understanding Lubrication and Taste Transport  
**Ashley Roye**, King's College London
- P2 Crystallisation and Melting Behaviour of Blends of Cocoa Butter Equivalents and Milk Fat by Studied Small- and Wide-Angle X-ray Scattering  
**Molly Massey**, University of Leeds
- P3 Extraction-Induced Structural Variations and Their Role in the Tribological Performance of Mung Bean Protein  
**Konstantina Eleni Christofilea**, King's College London
- P4 Ideal production conditions of edible coatings for food using Gum Arabic stabilised oleogel emulsions  
**Darrell Cobon**, University of Nottingham
- P5 Impact of Rice Protein and Low-Acyl Gellan Gum on the Physicochemical Properties and Starch Digestibility of Gluten-Free Orzo  
**Qingsu Liu**, Division of Food, Nutrition and Dietetics, University of Nottingham
- P6 Influence of Psyllium Fibre on Starch Gelatinisation, Rheology, and Freeze–Thaw Stability  
**Gleb Yakubov**, University of Leeds
- P7 Towards understanding the mouthfeel of chocolate: viscoelastic behaviour of tertiary sucrose-oil-water suspensions  
**Zohreh Honarvar Shahroudi**, University of Leeds
- P8 Using Time Domain NMR relaxometry to investigate the microstructure of food matrices  
**Tatiana Monaretto**, Oxford Instruments
- P9 Whey protein isolate nanofibrils: microscopy-based insights into concentration- and time-dependent self-assembly  
**Ezgi Gizli**, University of Birmingham

## (Invited) Insights into wheat milling and breadmaking: A few of my favourite things

**Grant Campbell<sup>1</sup>**

<sup>1</sup>University of Huddersfield, UK

What lights my fire as a researcher is combining clever mathematical modelling with elegant experiments to reveal insights about the physics of processes that could not be elucidated any other way. Within the limits of my abilities and the complexities of my research field, this presentation will review some of the contributions I have made during 30 or so years of research into wheat milling and breadmaking.

My PhD on “The Aeration of Bread Dough during Mixing” required some difficult maths to reconstruct bubble size distributions to reveal the effect of mixer headspace pressure on dough aeration and bread structure. Later in my career, this maths led to me to develop a novel approach to describe particle size distributions resulting from milling of wheat into flour, eventually extending to modelling the compositional distributions of particles as well as their size distributions, and revealing a more precise understanding of how wheat breaks during roller milling.

Returning to bread dough aeration, understanding the rate of turnover of gas during mixing required some difficult population balance modelling supported by high quality experimental data, leading for the first time to quantification of the residence time of gas during dough mixing and an understanding of the limits of oxidation. Modelling and measuring gas production and retention during proving led to insights about bubble growth and a sensitive new method for measuring gas expansion capacity of doughs. My interest in bread aeration has led to some holistic perspectives on aerated foods more generally.

Most recently my interest has turned to synergistic benefits between the emerging biorefining sector and the food industry, in which the biorefinery context allows commercial production of novel fibre ingredients to support the well-being and sustainability agendas of the food industry. The most likely initial market for these fibres is as bread ingredients, but their performance in bread is complex. A new experimental and modelling approach using the Chopin Mixolab (patent pending) is revealing more precisely the effects of flour removal, replacement with fibre and adjustment of water on different aspects of dough behaviour and bread quality, to clarify precisely the behaviour of these fibres and combinations thereof, and to support the introduction and exploitation of this new class of healthy and functional ingredients.

All of these studies are contributing to and informing how I teach the topic of Multiphase Systems to my chemical engineering students. With wheat being (as I tell my students) arguably “the world’s most important particle” and bubbles “the world’s most important ingredient”, these research studies have given me the opportunity to engage with things as fundamentally important, in their own way, as classical physics!

# Solute Exclusion as the Basis for Periodic Ice Structures in Directional Freezing

**Yuechuan Lin**<sup>1</sup>

<sup>1</sup>Adolphe Merkle Institute, University of Fribourg, Switzerland

Freezing is a known process to create structure in foods, such as porosity in tofu. It has recently gained attention for engineering sustainable meat analogues. However, predicting the final structure in complex food matrices is difficult. This work focuses on modelling the periodic ice structure of aqueous salt solution during directionally freezing since salt is ubiquitous in food system and its effect on melting temperature is well understood.

Our approach provides a new perspective on the subject. Contrary to most literatures, we don't apply a binary alloy analogy which assumes the solute can be incorporated into ice. Instead, we assume the solute is excluded at the ice-water interface which is closer to reality. The difference has a fundamental impact on the growth dynamics of ice. It can be shown that, for a planar binary alloy growth, there exists a steady state, while, for planar growth of ice, the solute builds up at the interface indefinitely. It implies that total solute exclusion imposes a stronger condition on the existence of a steady state: "the solute must be transported, as concentrated solution, past the freezing front" which guarantees the existence of laminar structure and puts constraints on the morphology.

Our goal is to find the permissible periodic ice morphologies at steady state and then apply classical instability theory on the steady state ice morphology to identify the stability criterion.

## Sugar-Fat Substituted Icings: Plausible possibility or just a piping dream?

**Peter Cooper**<sup>1</sup>, Chris Holland<sup>1</sup>, and Anthony Fletcher<sup>2</sup>

<sup>1</sup>University of Sheffield, UK <sup>2</sup>Believe in Science, UK

Bakery goods like doughnuts are often coated or glazed using layers of confectionary icing: used to sweeten, enhance aesthetics, and improve shelf-life. While these sweet treats are enjoyed by consumers, they contain 5-18% fat and 50-90% sugar depending on the desired function. With rising concerns in the public health sector around HFSS foods, and growing demand for healthier alternatives, a low-fat, low-sugar icing needs to be developed.

Our aim is to fully replace the saturated fat content in icings with unsaturated oleogels, and replace 50% of the sugar with low calorie sweeteners. Beyond taste, this presents a lot of material challenges; matching process rheological properties and maintaining mouth-feel and texture is not an easy task for a non-Newtonian system with complex networks of polymeric and multiple phase interactions.

Utilising material science techniques including rheology, differential scanning calorimetry and microscopy; we've begun to deconstruct these icings. Our initial steps have characterised the non-Newtonian behaviour of icings: managing viscosity, and investigating structure-functions relationships in sugar and fat crystals. This presentation summarise the roles of fat: in creating texture through yielding, keeping ideal melting properties and limiting water mobility; and sugar: affecting humectancy and the final viscosity of mixtures.

We report partial sugar replacement leads to viscosity losses. Sugar solubility, granulation, and reduced glass transition temperature have been linked to this. Oleogels trialled have seen mixed results, with combined ethylcellulose-beeswax oleogels showing similar yielding and melting characteristics to palm, but with lower  $G'$  values, despite marked improvement from separate EC and BW oleogels.

## Processing of food powders: from microscopic interactions to macroscopic powder bulk behavior

**Roozbeh Valadian**<sup>1</sup>, and Filip Francqui<sup>1</sup>

<sup>1</sup>Granutools, Belgium

Understanding the flow of powders is essential in many industrial applications. Anyone working with powdered materials has once experienced processability problems like a lack of flowability, heavy sticking on pipes and machine surfaces, or variability in dosage among many other examples. The macroscopic behavior of powders is a direct consequence of the diverse microscopic interactions taking place at the scale of the particles. The flow of powders is the result of a complex multi-parameter interplay of these interactions. Therefore, a good understanding of the properties of the particles and the cohesive interactions is necessary to better predict the resulting behavior, as well as its sensibility to environmental parameters like relative humidity or process temperature. The processing of food powders can be particularly challenging. Especially, food materials are likely to build up electrostatic charges during processing. Furthermore, powder caking during storage can lead to loss of production and drift in material properties between the production and the reception from the customer. We will explore the properties of powders at different scales, from the interactions between the particles at the micro-scale to the consequence on the powder processability. The presentation aims to provide the required fundamental background on the physics of powders. Then, the audience will learn how this new knowledge can be used to better understand the processability of powders through detailed case studies applied to food powder processing.

## (Invited) Ten years of Food Physics

**Megan Povey**<sup>1</sup>

<sup>1</sup>University of Leeds, UK

Over the past ten years very significant advances have been made in the physics underpinning food processing and formulation. Perhaps the biggest change is the use of artificial intelligence (AI) in sensor fusion and data interpretation and food design. Whilst machine learning (ML) has been in use for decades in the form of neural networks, the integration of large language models (LLMs) with ML (LLMs + ML + deep neural networks = AI) has produced a new paradigm for process control and measurement in food factories. Innovations include 2015: Soft-matter frameworks applied to food structure design. 2016: Advances in thermophysical property measurement for process optimization 2017; High-pressure processing (HPP) and pulsed electric fields (PEF) gain traction. 2018 Nanoemulsion and particulate control for texture and stability. 2019 3D food printing enters commercial prototyping. 2020 Cultivated meat physics: fluid mechanics and scaffold design. 2021 AI-driven rheology prediction and machine learning integration. 2022 Digital twin systems for real-time process simulation. 2023 Large-amplitude oscillatory shear (LAOS) for nonlinear rheology. 2024 Cold plasma and sustainability-focused processing innovations. 2025 Integrated AI + physics frameworks for personalized food design.

# Elemental and Microstructural Composition of Instant Pounded Yam Flour Evaluated by Energy Dispersive X-Ray Spectroscopy in a Scanning Electron Microscope System

**Ekpereka Anajekwu<sup>1</sup>**, Terri Grassby<sup>1</sup>, Claudio Avignone-Rossa<sup>1</sup>, and Bolanle Oloyede<sup>1</sup>

<sup>1</sup>University of Surrey, UK

Yam is an important tuber crop; particularly in African and Asian countries, it is consumed as a staple food. This study analyzed two varieties of yam (Puna and Punjo), processed into instant pounded yam flour by peeling, slicing, parboiling, oven or freeze drying before milling into flour. The different yam samples were analyzed for mineral and structural composition by using an economical technique called Scanning Electron Microscope—Energy Dispersive X-ray Spectroscopy (SEM-EDX). The results showed that there is a significant difference ( $p < 0.05$ ) in the elemental content of the yam samples such as carbon (C), nitrogen (N), oxygen (O), and potassium (K). The main trends showed that all yam samples contained low or no sodium (Na), and silicon (Si) at a safe level. On the other hand, other minerals detected in some samples were magnesium (Mg), phosphorus (P) and Sulphur (S). The SEM images showed different shapes ranging from oval shapes, large block masses and irregular structures depending on the samples as affected by varieties and drying methods. The structures of yam samples revealed the binding of starch particles with other components such as fiber and protein which provides additional information of their functionality and cooking properties. In conclusion, SEM-EDX offered a reliable and fast approach to detect the minerals in different food samples when compared with other methods of measurement such as ICP-OES and the differences in elemental contents in the study may refer to the influence of different factors such as varieties and drying methods.

(Invited) Who/what is food physics for?

**Wilson Poon**<sup>1</sup>

<sup>1</sup>University of Edinburgh, UK

On this 10th anniversary of the Food Physics Group, initially the Physics in Food Manufacturing Group, I want to reflect on the question of whether physics has been 'good for food'. I will explain why I think that while physics may indeed have been a good thing for food manufacturing, its legacy for consumers may have been more mixed, and make some suggestions on what a food physics that prioritises the eating public may look like, particularly in the area of soft matter.

## Multi-functional structuring behaviour of jellyfish biomatrices

**Mie Pedersen**<sup>1</sup>, Matías Via<sup>1</sup>, Paul Kempen<sup>2</sup>, Thomas Vilgis<sup>3</sup>, and Mathias Clausen<sup>1</sup>

<sup>1</sup>University of Southern Denmark, Denmark <sup>2</sup>The National Centre for Nano Fabrication and Characterization, DTU Nanolab, Technical University of Denmark, Denmark <sup>3</sup>Max Planck Institute for Polymer Research, Germany

Jellyfish biomatrices contain a complex combination of biopolymers and natural ions that may serve as functional structuring agents in sustainable food systems. Here, we examine the emulsification and stabilization properties of jellyfish biomatrix powders using rheology, CARS microscopy, cryo-SEM, and image analysis. Desalting the biomatrix improved emulsion stability, producing smaller droplets, narrower size distributions, and increased elasticity associated with closer droplet packing. Native high-salt biomatrices formed less stable emulsions initially but developed increased elasticity during storage, enabling emulsion-templated oleogel formation upon drying. These findings demonstrate how salt content and pH modulate the functional behavior of jellyfish biomatrices and highlight their potential as minimally refined materials for sustainable soft-matter food structuring.

[1] Pedersen, M. T., Via, M. A., Kempen, P., Vilgis, T. A., and Clausen, M.P. (2026). Multi functional food structuring ingredients from jellyfish. *Food Hydrocolloids*, 173, 112220. <https://doi.org/10.1016/j.foodhyd.2025.112220>.

## (Invited) Colloidal Particles and Droplets in Granular Dispersions: Modulating Grain Interactions, Sintering and Flowability

**Krassimir Velikov**<sup>1,2,3</sup>

<sup>1</sup>Unilever Innovation Centre, The Netherlands, <sup>2</sup>Institute of Physics, University of Amsterdam, The Netherlands, <sup>3</sup>Soft Condensed Matter, Debye Institute for NanoMaterials Science, Utrecht University, The Netherlands

The behavior of granular materials composed of hard grains—such as salts, sugars, ice crystals, and fats—can be critically influenced by the presence of colloids. Colloidal scale particles and droplets can affect the inter-grain interactions, with significant implications for sintering, caking, and flowability. This presentation explores the role of colloidal dispersions in granular matter and how these affect grain interactions, sintering, and their mechanical properties and flowability. Case studies from food applications illustrate how targeted use of colloidal particles and emulsions can control texture, stability, and processability in oil and water continuous systems. Understanding these mechanisms opens new avenues for designing structured solids and functional powders with tailored performance.

# Multiscale Insights into Chocolate and Compound Matrices: Linking Refining Technology, Particle Size, and Fat Content to Rheological and Lubricating Behaviors

**Clémence Gallery**<sup>1</sup>

<sup>1</sup>Cargill France SAS, France

Understanding the interplay between rheological and tribological properties in chocolate and compound matrices is essential for optimizing both processing and sensory performance. This study explores how fat content, particle size distribution (PSD), and refining methods influence the rheological (flow) and tribological (lubrication) properties of dark, milk, and white chocolates and their compound counterparts. Using a multiscale approach, rheological characterization via continuous shear ramp testing was combined with soft-tribology measurements simulating oral conditions [1]. Key findings include that higher fat content (25–55%) reduces yield stress and viscosity, acting as a lubricant without changing shear-thinning behavior [2]. Particle size (22–44  $\mu\text{m}$ ) and refining technique (dry vs. roller refining) also significantly impact flow and friction: smaller particles increase viscosity and friction, while roller refining lowers flow resistance due to broader PSD and irregular shapes. Tribological results showed that friction decreases with sliding speed and fat content but increases with smaller particles. Chocolate and compound matrices followed different friction trends with fat increases — exponential and sigmoidal, respectively — highlighting threshold effects in lubrication. This integrated framework offers predictive tools for optimizing chocolate formulation and processing, with novel insights into how composition and processing jointly shape sensory and processing performance.

[1] Rodrigues, S.A., Selway, N., Morgenstern, M.P., Motoi, L., Stokes, J.R., & James, B.J. (2017). *Food Funct.*, 8, 533.

[2] Gallery, C., Bourge, S., & Agoda-Tandjawa, G. (2024). *Journal of Food Engineering*, 363, 111780.

## Soluble Amylose Chains Inhibit Gelatinisation and Retrogradation in Waxy Corn Starch

Thoithoi Tongbram<sup>1,2</sup>, Lathika Vaniyan<sup>1</sup>, Thomas MacCalman<sup>1</sup>, Avanish Bharati<sup>3</sup>, Frederick Warren<sup>4</sup>, Laxmikant Shivnath Badwaik<sup>2</sup>, Pallab Kumar Borah<sup>5</sup>, and **Gleb Yakubov**<sup>6</sup>

<sup>1</sup>University of Nottingham, UK <sup>2</sup>Tezpur University, India <sup>3</sup>Forschungszentrum Jülich GmbH, Germany <sup>4</sup>Quadram Institute Bioscience, UK <sup>5</sup>Heinz Maier-Leibnitz Zentrum, Technical University of Munich, Germany <sup>6</sup>University of Leeds, UK

In this study, soluble amylose chains with varying degrees of polymerisation (DP 186–4020) were isolated via isoamylase debranching of amylopectin from native and waxy corn starches. When these soluble amylose chains are mixed with aqueous suspensions of waxy corn starch, spontaneous adsorption onto the surface of starch granules occurs. The resulting coating envelops the granules and markedly inhibits gelatinisation, increasing the onset temperature by up to 10 °C. Additionally, the amylose coating alters the pasting and short-term retrogradation properties of waxy corn starch, as evidenced by a reduction in trough viscosity, up to a 20 % decrease in breakdown viscosity, and approximately a 50 % increase in setback viscosity. This effect is both concentration- and DP-dependent.

We found that chains with a critical length of  $200 \leq DP \leq 700$  produce the most pronounced effect and exhibit the strongest concentration dependence, suggesting that entropic considerations play a key role in starch–amylose interactions. Complementary analyses – including calorimetry, viscosity, turbidity measurements, and small-angle X-ray scattering – confirmed the inhibited gelatinisation and retrogradation. X-ray diffraction data further corroborated that the adsorbed amylose forms a hydrated, V-type-like polymorphic envelope.

We hypothesise that this amylose coating restricts water ingress and inhibits granular gelatinisation, providing a physical basis for the observed inhibition. These findings highlight a previously undocumented role of soluble amylose chain length in directing starch thermal and structural transitions. In addition, our results offer a novel route for designing starch systems with enhanced functionality for applications in food processing and in (bio)material design.

# Stretch, Aim, Shoot! Probing Polymer Network Structure During Elongational Flow Using Synchrotron CaBER–SAXS: In Pursuit of Improved Texture of Alternative Meat

Lathika Vaniyan<sup>1</sup>, Nick Terrill<sup>2</sup>, Pallab Kumar Borah<sup>3</sup>, Joshua Reid<sup>1</sup>, Stefan Baier<sup>4</sup>, and Gleb Yakubov<sup>5</sup>

<sup>1</sup>University of Nottingham, UK <sup>2</sup>Diamond Light Source, UK <sup>3</sup>Heinz Maier-Leibnitz Zentrum, Technical University of Munich, Germany <sup>4</sup>University of Queensland, Australia <sup>5</sup>University of Leeds, UK

The creation of realistic fibrous textures remains a central challenge in developing alternative and plant-based meat products. Among various structuring techniques, fibre spinning has emerged as a promising route to mimic muscle-like anisotropy. Achieving consistent filament formation, however, requires a detailed understanding of molecular alignment and network evolution during fluid elongation and filament rupture.

In this study, we integrated real-time Small-Angle X-ray Scattering (SAXS) with a Capillary Breakup Extensional Rheometer (CaBER) to probe nanoscale structural changes during filament stretching and failure. Time-resolved SAXS patterns were recorded before and during elongation, as well as at the point less than 100 ms prior to filament rupture. These experiments enabled the correlation of macroscopic rheological behaviour with molecular-scale rearrangements.

Experiments on mixed NaCMC–NaCas hydrogel systems revealed that increasing precursor concentration to 0.75% NaCMC (sodium carboxymethylcellulose) and 0.75% NaCas (sodium caseinate) improved scattering signal quality, while higher NaCas contents (up to 4.5%) produced a distinct SAXS peak at  $q \approx 0.02 \text{ \AA}^{-1}$ , indicative of protein ordering. During elongation, scattering intensity decreased and the correlation length shortened, reflecting progressive molecular stretching. At elevated NaCas concentrations, incomplete crosslinking limited these structural changes, highlighting the interplay between network connectivity and extensional response.

This combined CaBER–SAXS approach enables direct visualisation of structural dynamics during filament thinning, offering simultaneous mechanical and nanoscale insight inaccessible via microscopy or conventional rheology alone. The results advance our understanding of structure–function relationships in biopolymer networks and support the rational design of fibre-forming formulations for improving the texture of next-generation plant-based meat products.

## A kinetic model fitting approach to quantify water mobility in mycoprotein paste using osmotic dehydration

**Rosa Selene Espiricueta Candelaria**<sup>1</sup>, Karen Robertson<sup>2</sup>, Peter Harvey<sup>3</sup>, Stewart J. Radford<sup>4</sup>, and Vincenzo di Bari<sup>1</sup>

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<sup>2</sup>Advanced Materials Research Group, Faculty of Engineering, University of Nottingham, UK <sup>3</sup>Sir Peter Mansfield Imaging Centre - School of Medicine & School of Chemistry, University of Nottingham, UK

Understanding water mobility in multicomponent food matrices is fundamental for advancing energy-efficient processing methods. Mycoprotein (MP), derived from *Fusarium venenatum*, consists of approximately 75% water manifesting as bound, unbound, and entrapped states, each critical for determining its structural stability and behaviour during processing. This study introduces a standardized application of osmotic dehydration (OD) to MP paste to systematically characterize these water fractions via kinetic modelling. MP samples sculpted into uniform cylinders using dialysis tubing and rigid moulds were immersed in 65 °Brix sucrose solution at controlled temperatures (11, 21, and 31 °C) for 120 minutes. Water loss (WL), sucrose mass gain (MG), and water activity (*a<sub>w</sub>*) were quantified at specified intervals. WL kinetics adhered to Peleg's model, while the temperature effect on water transport was assessed using Arrhenius analysis of the Peleg rate constant (*k<sub>p</sub>*). Light microscopy was deployed to observe hyphal microstructure before and after OD. Results showed high reproducibility in WL measurements due to geometric standardization, with significant water removal at elevated temperatures (WL reached 25.3% at 21 °C and 30.6% at 31 °C after 60 minutes). The OD process selectively extracted mobile water without visible hyphal deformation, confirming the integrity of the fungal matrix. Elevated activation energy (24.3 kJ/mol) indicated temperature-dependent diffusion as the main transport mechanism. This new OD-based approach enables precise quantification of water fractions and supports process optimization for alternative proteins, offering scalable potential for more sustainable, energy-saving food manufacturing.

## Multi Speckle – Diffusing Wave Spectroscopy – an accurate tool to study structural properties of dairy products

**Roland Ramsch**<sup>1</sup>, Matthias Lesti<sup>1</sup>, Loubnah Belahcen<sup>2</sup>, and H el ene Tormo<sup>2</sup>

<sup>1</sup>RR Consultings (Speclz), France <sup>2</sup>Ecole D'Ing nieurs Purpan, France

Textural properties of dairy products are part of consumers choice criteria. If the texture of a yoghurt do not match the expectation of the consumer, the product will not be successful. Yoghurts present a wide range of products (Greek yoghurt, drinking yoghurt, set-type, etc.) with rheological properties from almost liquid to strong gels.

Speclz presents Multi-Speckle Diffusing Wave Spectroscopy (MS-DWS) [1,2], an optical technique based on multiple backscattering of laser light. The backscattered photons form a speckle image, which is recorded with a camera. The temporal evolution of the speckle image is directly correlated to the mobility of the scatterers. In the case of milk, these are mainly the casein micelles. As the mobility of the casein micelles decreases with the ongoing fermentation, our MS-DWS technique can monitor the gelation kinetics and the gel strength. The technique does not need any dilution or sample preparation, and the gelation takes place in the sample holder without macroscopic perturbation.

This work will present the physics behind the measurement technique and how it can be used in dairy product research. The accurate results were used to develop a preliminary predictive model on textural properties of set-type yogurts. This will help to screen new recipes.

[1] D. J. Pine, D. A. Weitz, A. Zhu, e., Herbolzheimer, Journal of Physics 1990, 51, 26.

[2] D. A. Weitz, D. J. Pine, Diffusing-Wave Spectroscopy. In Dynamic light scattering; Oxford University Press: New York, 1993, 652.

## Shear-induced structure formation of protein microparticles

**Maïke Segers**<sup>1</sup>, Starla Liu<sup>1</sup>, Krassimir Velikov<sup>1</sup>, Mehdi Habibi<sup>2</sup>, and Peter Schall<sup>1</sup>

<sup>1</sup>University of Amsterdam, The Netherlands <sup>2</sup>University of Wageningen, The Netherlands

The structuring of protein aggregates is key to the texture and sensory qualities of many foods, yet the underlying physical mechanisms of gel formation remain poorly understood. For the next generation of plant-based fibrous meat analogues, the development of more efficient protein networks with well-defined pore structures and anisotropy is beneficial to improve juiciness and overall consumer acceptance.

We have shown previously that protein aggregation under quiescent conditions can be understood as a nonequilibrium percolation process. Here, we show how the application of shear can be used to structure the protein aggregates into dense slab-like phases. We use spherical, micron-sized protein aggregates as models for primary aggregates, and a confocal microscope equipped with a rheometer head to directly visualize the particle-scale structures that form under shear. This allows us to distinguish two regimes: high attraction close to the proteins' isoelectric point, where fractal aggregates form and break under the applied shear and a regime of mild attraction, far above the isoelectric point, where the shear leads to dense, slab-like structures. Using particle tracking, we elucidate the formation of these structures in detail.

These results give key insights into structuring of meat alternatives produced by extrusion or shear cell technology. In the future, we will link our findings to bulk rheology and sensory studies conducted at Wageningen University, to develop design principles for the creation of better meat alternatives.

## Posters

### Biomimetic Modelling of Oral Mucus Microstructure for Understanding Lubrication and Taste Transport

**Ashley Roye**<sup>1</sup>, Kian Kun Yap<sup>1</sup>, Abby Weston<sup>1</sup>, Tom Reddyhoff<sup>3</sup>, Nicholas Spencer<sup>2</sup>, Robert Lucas<sup>4</sup>, Richard Lynch<sup>4</sup>, Sorin-Cristian Vlădescu<sup>1</sup>, and Guy Carpenter<sup>1</sup>

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Taste perception and oral food processing arise from interactions between tastant molecules and the salivary/mucus layers coating the oral cavity. Mucins—large, heavily glycosylated proteins making up saliva and the mucosal lining—mediate tastant transport to taste buds and strongly influence lubrication, mouthfeel, and textural sensation. The mucus layer functions as a hierarchical soft-matter structure composed of tethered and gel-forming mucins rather than a uniform sheet; simplified models therefore fail to represent its biochemical and biophysical complexity. This work aims to investigate food–mucus interactions by developing a model that more accurately reflects the microstructure of oral mucosa.

Mucins are notoriously difficult to purify and immobilise. To improve success, the model uses recombinant expression of the tethered mucin MUC1 in bacterial or mammalian systems, producing non-glycosylated or glycosylated proteins that selectively bind gel-forming MUC5B. Purified mucins were immobilised on functionalised surfaces to characterise tribological lubrication properties and on 96-well plates to assess mucin–mucin binding and tastant retention. Immobilised mucins reduced friction substantially: MUC5B achieved superlubricity, while MUC1 alone provided moderate yet significant lubrication. MUC1 was immobilised via a polyhistidine tag, enabling controlled binding of MUC5B and to form a hierarchical structure resembling native mucus.

Future work will examine tastant binding and the influence of mucin glycosylation on these interactions. By providing a more biophysically relevant platform for studying oral lubrication and tastant transport, this model may clarify mechanisms underlying taste perception and support the development of sustainable plant-based foods and healthier low-salt or low-fat products with improved sensory quality.

## Crystallisation and Melting Behaviour of Blends of Cocoa Butter Equivalents and Milk Fat by Studied Small- and Wide-Angle X-ray Scattering

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Fat crystallisation governs key aspects of chocolate quality, including texture, gloss, and shelf stability. Cocoa butter (CB) polymorphism is central to these properties, but increasing demand for cost-effective, sustainable, and plant-based products has driven interest in cocoa butter equivalents (CBEs). Their successful use depends on replicating the desirable qualities of CB through careful formulation. Anhydrous milk fat (AMF) has traditionally been used in milk chocolate to influence texture, polymorphic transitions, and melting profiles. As plant-based 'milk' chocolate grows in popularity, understanding the functional role of milk fat is essential.

This study investigates how AMF addition affects the crystallisation behaviour of CBE blends. Small- and wide-angle X-ray scattering (SAXS/WAXS) and differential scanning calorimetry (DSC) were used to analyse POP-, POS-, and SOS-rich CBEs through controlled melting and cooling cycles, with electron density profiles calculated using Fourier transformation.

Results showed that AMF significantly modified crystallisation kinetics, accelerating early nucleation but delaying the formation of stable polymorphs. SAXS/WAXS patterns revealed increased polymorphic diversity, with distinct emergence of 3L and 4L phases corresponding to metastable, less ordered crystal structures. These phases are associated with softer textures and reduced bloom resistance. AMF-containing blends also showed lower solid fat content and decreased melting points, indicating a pronounced plasticising effect. Increased lattice spacings suggested disrupted triacylglycerol packing due to shorter-chain and saturated fatty acids, producing greater molecular disorder and weaker crystalline networks.

Replicating these structural and thermal effects in dairy-free systems remains a key challenge. Future work focuses on milk fat replacer blends.

# Extraction-Induced Structural Variations and Their Role in the Tribological Performance of Mung Bean Protein

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The sensory performance of plant-based foods is often limited by the suboptimal oral lubrication and astringency of their protein components. These undesirable properties arise from complex, yet insufficiently characterised, interactions at the protein–saliva interface. The central hypothesis of this work is that the frictional behaviour of plant proteins is controlled by their microstructure, which is determined by both protein source and, critically, extraction methodology.

This study systematically evaluates how extraction-induced structural variations in mung bean protein influence boundary lubrication under physiologically relevant oral conditions. Proteins were isolated using distinct extraction methods chosen to generate diverse protein structural states. Differences in molecular integrity and subunit composition were confirmed by SDS-PAGE. Lubrication performance was quantitatively evaluated using a reciprocating pin-on-disc tribometer at multiple protein concentrations. Gelation properties were also investigated to characterise the capacity for nanoscale network formation, a key determinant of interfacial film development.

This research aims to define structure–function relationships between extraction method, protein assembly, and interfacial friction. Ongoing work integrates tribological data with particle size and morphology analysis via scanning electron microscopy and in situ visualisation of protein film formation and protein–saliva interactions using laser-induced fluorescence. These insights are expected to provide a mechanistic foundation for the design of plant-based foods with enhanced oral lubrication and improved mouthfeel.

## Ideal production conditions of edible coatings for food using Gum Arabic stabilised oleogel emulsions

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The ability of food grade Gum Arabic from Acacia Senegal to stabilise rapeseed oil/rice bran wax (RBW) oleogel in water emulsions was investigated using Particle Size analysis, light microscopy and Force Tensiometry initially, followed by Rheometry and Differential Scanning Calorimetry. This combination of commonly used food ingredients was identified as a potential base for an edible coating which could provide a sustainable alternative to plastic packaging for suitable fruits and vegetables. Samples were prepared by high-speed homogenisation at various speeds, and with varying composition in relation to emulsifier concentration, dispersed phase concentration and wax concentration. Initial experiments assessed the base oil in water emulsion, then later the effect of RBW addition was analysed. RBW increased viscosity of the emulsion, reduced particle size and improved stability compared to the control emulsion. Optimum process parameters identified were 8 % emulsifier to dispersed phase ratio, 20 % dispersed phase to continuous phase ratio, with 5 % Rice bran wax to dispersed phase ratio, at 8000 rpm homogeniser speed, based on the most favourable results from the analysis performed.

# Impact of Rice Protein and Low-Acyl Gellan Gum on the Physicochemical Properties and Starch Digestibility of Gluten-Free Orzo

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Rice is inherently gluten-free, making it a valuable food resource for individuals with gluten sensitivity. However, its high content of rapidly-digestible starch limits its potential as a low-glycaemic index (GI) staple. This study investigates the effects of rice protein (RP) and low-acyl gellan gum (LAGG) on the physicochemical properties and reduction in starch digestibility of a rice-based orzo—a rice-shaped pasta designed as a versatile, low-GI, gluten-free alternative.

Formulations were prepared using rice flour alone or partially substituted with RP (9%, w/w) and/or LAGG (1%, w/w), with an additional treatment in which LAGG was added to the cooking water. Pasting behaviour, microstructural characteristics, and textural properties were analysed to investigate RP–starch–hydrocolloid interactions. Incorporation of RP and LAGG resulted in distinct pasting profiles, characterised by increased setback viscosity, indicating enhanced short-term restructuring of the starch network. Cooked orzo exhibited reduced cooking loss and improved structural integrity compared to the rice flour-only control. Textural analysis revealed that RP enrichment produced softer, more extensible orzo, while LAGG increased firmness, depending on its incorporation into the dough or cooking water.

Starch digestibility was evaluated using static and semi-dynamic *in vitro* digestion models to simulate oral, gastric, and intestinal phases. RP- and LAGG-containing formulations reduced starch digestion rates and predicted GI, with the combined RP and LAGG formulation showing the most significant reduction, likely due to synergistic network strengthening and enzyme diffusion limitation. These results demonstrate that RP and LAGG are effective structuring agents for developing gluten-free orzo with improved cooking quality and a lower-GI potential.

# Influence of Psyllium Fibre on Starch Gelatinisation, Rheology, and Freeze–Thaw Stability

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The addition of *Plantago ovata* husk (psyllium) to starch-based foods is valued for its nutritional and functional benefits, particularly in maintaining texture and stability during storage. However, the mechanisms underlying its interaction with starch remain poorly understood. This study examines composite gels prepared from *Plantago ovata* mucilage (POM) and five starches varying in amylose content and granule size. Gels were evaluated when fresh, after five days at room temperature, and following a five-day freeze–thaw cycle.

Distinct stability behaviours were observed under ambient and freeze–thaw conditions. Oscillatory rheology revealed a stabilising effect of POM on the viscoelastic properties of starch composite gels, especially after freeze–thawing, where starch gels without POM exhibited consolidation and brittle failure. The mechanism of composite formation appears to stem from the ability of POM to form an occlusive film around starch granules. The resulting microstructure depends on competitive interactions between POM and starch for space and water.

In particular, POM and waxy corn starch (amylopectin) compete for spatial distribution, while starches with higher amylose content exhibit more compatible interactions. The smaller granule size of rice starch promotes a well-dispersed microstructure that enhances composite stability and reduces syneresis.

Overall, these findings highlight the functionality of *Plantago ovata* mucilage in developing starch-based formulations with improved mechanical resistance, freeze–thaw stability, and water retention - offering new opportunities for creating high-resistant starch systems with superior techno-functional properties.

## Towards understanding the mouthfeel of chocolate: viscoelastic behaviour of tertiary sucrose-oil-water suspensions

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Oral processing of chocolate is critical for its sensory perception and is highly complex. This complexity arises from the melting of the fat phase and its mixing with saliva, combined with sucrose dissolution. This work focuses on understanding the behaviour of oil–sucrose suspensions during the initial stages of saliva ingress. The process is mimicked by using an oil–sucrose suspension with the addition of water as a secondary fluid.

For suspensions with a water/sucrose mass fraction in the range of 0.175 – 0.370, we observe macroscopic phase separation marked by the formation of complex, water-continuous tri-phase suspensions. These suspensions consist of undissolved sucrose crystals dispersed in sucrose solution, with significant amounts of oil entrapped within the jammed structure. Contrary to expectations, these complex suspensions are flowable yet exhibit pronounced viscoelasticity, with  $G' > G''$  across a broad range of frequencies and shear strains. Stress relaxation experiments reveal that these suspensions have a complex relaxation spectrum characterised by multiple relaxation terms, consistent with microscopic observations of multiple length scales of partially dissolved sucrose crystals and entrapped oil droplets. Our key hypothesis is that preferential dissolution of smaller sucrose crystals leads to the formation of a weakly jammed, yet highly associated assembly of sucrose crystals reinforced by oil droplets, which act as the secondary fluid.

These findings underscore the critical role of particle solubility in controlling the rheological properties of tertiary sucrose–oil–water suspensions and provide new insights into the breakdown of complex foods during oral processing.

## Using Time Domain NMR relaxometry to investigate the microstructure of food matrices

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Understanding the microstructural dynamics of food systems is essential for optimising texture, stability, and sensory quality. This approach utilises Time Domain Nuclear Magnetic Resonance (TD-NMR) relaxometry to investigate proton mobility in cereal-based products and plant-based meat (PBM) analogues, with a focus on water and lipid distribution during processing and storage.

In cereal-based matrices such as cakes,  $T_2$  (transverse) relaxation profiles, obtained using inverse Laplace transform (ILT) data processing, reveal distinct proton populations associated with low- and high-mobility water and lipids. A decrease in water mobility during storage correlates with increased matrix rigidity, offering valuable insights into the macroscopic textural properties of these products.

A similar approach is applied to PBM burgers, where TD-NMR enables the characterisation of water and lipid mobility within the matrix and allows real-time monitoring of structural changes during freezing, thawing, and cooking. In this study, commercial PBM burgers from different brands exhibited distinct water and lipid distribution patterns, attributed to differences in internal product structure. Additionally, as temperature increases, the  $T_2$  distribution reveals shifts in proton populations, indicating internal structural transformations within the PBM burgers during the 'simulated cooking process'. These molecular-level insights are closely linked to sensory attributes such as juiciness and mouthfeel, highlighting the potential of TD-NMR relaxometry as a powerful tool for understanding and optimising food texture and quality.

Overall, TD-NMR relaxometry proves to be a non-destructive and effective technique for characterising food matrices, supporting R&D efforts in both traditional and alternative food systems.

## Whey protein isolate nanofibrils: microscopy-based insights into concentration- and time-dependent self-assembly

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Protein nanofibrils are  $\beta$ -sheet rich supramolecular structures formed through ordered peptide self-assembly under defined denaturing conditions. The fibrils' high aspect ratio, rigidity, and capacity to organise into entangled colloidal networks make them a promising component for structure creation in soft-matter foods. In applications, they enhance viscoelasticity, gelation, and structural integrity. Such fibrillation behaviour has commonly been reported for  $\beta$ -lactoglobulin, known as the main fibril-forming component in whey protein isolate (WPI).

This study investigates WPI fibrillation and associated phase behaviour under controlled acidic heating (pH 2, 80 °C) across a range of incubation times and protein concentrations. Brightfield and polarised-light microscopy were used to visualise early assembly and concentration-dependent structural organisation. Progressive heating promoted the emergence of birefringent, fibrillar structures, consistent with the literature. At intermediate concentrations (ca. 2 – 4 wt%), microscopy revealed the coexistence of dispersed fibrils with spherulite-like assemblies. The abundance and dimensions of these structures increased with incubation time. On the contrary, an increase in protein concentration promoted more continuous networks and resulted in a reduction in the number density of spherulites. These were no longer observed above ca. 6 wt% of WPI, which coincided with the onset concentration of gelation. Our results thus far confirm that acidic heat treatment drives WPI into fibrillar structures whose morphology shifts with incubation time and concentration. Future research will explore the application of these structures for the creation of multiscale fibrillar structures. Once we have proof of concept, we will direct our research toward non-animal protein sources.

**Food Physics 2026**  
**4-5 February 2026**  
Arla House, Leeds, UK