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EDITORIAL Food Colloids 2025

TOPIC:

Trending new food materials & technologies

Consumer requests for new, sustainable and high-quality safe foods is urging the food industry to innovate and invest in new technological concepts to allow them to come up with new or better food materials and processes. Therefore, food science & technology is becoming an increasingly competitive and dynamic research field. Moreover, the awareness of consumers of what they eat and, more importantly, in what they *want* to eat and what *not* to eat, is becoming increasingly pronounced. Paramount is still the desire for products that have good taste, texture, stability and appearance, as well as good nutritional value and competitive price. However, at the same time, consumers increasingly desire a sustainable and secure food system that reduces greenhouse gas emissions and other pollutants, in other words, farming systems that are more in harmony with Nature [1].

The evolution of the science and technology of *sustainable* food products is therefore progressing rapidly. Under the radar of food scientists and developers is making food products that not only taste good, but also the building up of novel focus areas or sectors that will help society to come up with new solutions to current environmental and health challenges. Examples of new sectors are artificial intelligence for advancing fundamental understanding, big data in food and agriculture, smart sensing for intelligent food packaging, robotics for food processing and blockchain technologies for improved food safety.

A major and already recognized trend in the field has been the development of plant-based food products, in which animal-based ingredients are exchanged with plant-derived ones. According to the Good Food Institute (GFI) [1], the market for plant-based food products has shown remarkable growth in recent years - one of the fastest growing sectors in the food industry. However, in the last 2-3 years performance within this market has varied widely and some parts of this sector even started to decline [1]. The main reasons for this decline appear to be largely cost related, i.e., the plant-based product costs were substantially higher compared with comparative animal-based products. However, according to the GFI, the long-term future will see sustained growth in plant-based products if they are able to deliver on better on key consumer quality drivers such as taste, texture & price. Since many of these product qualities are intimately connected with the colloidal structure of foods, a better understanding of the colloidal and structural properties of these plant-based foods will be indispensable if this market growth is to be achieved. With this in mind, the following articles we selected for publication in this COCIS 2025 Food Colloids section.

The articles deal mainly with three different science themes:

i) **New colloidal food systems and processes creating improved functionality**

Phan & Bhandari discuss the application of nanobubbles (NBs) in food systems. Food grade NBs are known as ultrafine gas bubbles with a diameter less than 1 μm, owing to unique features, such as outstanding stability, high internal pressure and an extensive surface-to volume ratio. NBs can significantly facilitate various food processes and related products, as well as enhance food safety and functionalities.

Pickering water-in-water emulsions are described by **Wang et al**. These systems have gained research attention due to their unique rheological and tribological performance. For the stabilization of these emulsions, it is generally necessary to have a good level of particle coverage at the W/W interface. The properties of the particles and the environmental factors affect their adsorption and aggregation behaviour and subsequently the overall tribological performance, as discussed.

Beldring et al. review the role of exocellular polysaccharides from lactic acid bacteria (LAB) to improve the structure of fermented milk matrices. During fermentation, LAB simultaneously reduce the pH by secreting lactic acid and producing exocellular polysaccharides (ExoPS). The development of simplified model systems has so far led to a mechanistic understanding of the impact of LAB in texturizing yogurt. However, the colloidal interactions at play between the various components within the fermentation matrix have been grossly overlooked. This review focuses on the recent research efforts which could aid linking the mechanisms of structure formation at various length scales to the final, bulk quality of the fermented products,

For a long time, fats and oils were the primary ingredients targeted for reduction or even elimination in foods due to health concerns. In the article by **Schafer et al.**, the authors stress that recent work comes to the conclusion that fats & oils can also offer great new opportunities to bring forward new technical advantages in food production. Examples are the formation of oleogels (oil structuring) or oleofoams (air-in-oil foams). These structures not only allow one to create new texture perceptions, but can also confer other attractive sensory properties.

Bach & Rühs elaborate on freeze structuring (FS), a process that allows precise control over the pore morphology formed after freezing of colloidal suspensions. Since food systems are often inherently complex aqueous mixtures of polysaccharides, proteins, and fats, the interactions within these multi-component blends are much less explored than single-component systems. Freeze structuring is a unique processing technology that uses ice crystal formation as a template to create fibrillar, lamellar, and cellular structures with varying pore sizes in colloidal systems. This review explores how polysaccharide and protein suspension properties affect FS and provides guidelines for optimizing food raw materials to achieve structural control.

ii) Comparing colloidal and structural properties of plant-based alternative food products with their animal-based ‘reference’ systems

Hu et al. compare the colloidal and structural properties of plant-based milk alternatives (PMAs) with corresponding animal-based milks. PMAs, generally speaking, show a lower colloidal stability than animal-based milks, mainly lower stability of protein particles and oil droplets. Furthermore, high levels of protein and fat can lead to more sedimentation and phase separation due to the fact that the protein in PMAs typically originate from water-insoluble protein bodies, which are present as large particles. Unlike the highly structured casein micelles in mammalian milk, these PMAs particles lack a stable architecture and tend to aggregate further during processing and storage. In order to improve physical stability, one approach could be to design protein particle mixtures that better resist aggregation, i.e., by creating hybrid protein particles.

Ahrné & Leser analyse the colloidal properties of classic, dairy-based cheese and with respect to plant protein-based cheese analogues. From a colloid science point of view, dairy cheese is a material that consists of a gel phase (curd) that is created and controlled by the aggregation of the casein proteins. To understand the mechanisms of gel formation, we need to describe the nature of the interactions between the proteins in their molecular form and their aggregates. Major differences between the caseins and the plant-based proteins are i) the caseins are flexible whilst the plant proteins are globular, and ii) the caseins are more soluble (dispersible) in water than the plant-based proteins that show significant aggregation. As a consequence, commercial dairy and plant-protein based cheese alternatives are macroscopically very different products.

iii) The use of innovative tools for the creation of novel value-added properties

Plant proteins are emerging as a more sustainable and ethical alternative to established animal proteins for the interfacial stabilization of emulsions and foams. In this framework **Lin et al.** introduced the 'Alternate Subphase Tensiometry' (AST) as a novel method to map literature data on interfacial tension reduction of novel protein sources. This method allows the mapping of interfacial tension data from 57 studies investigating the adsorption of various plant proteins at various o/w interfaces. AST is a promising new tool to collect and reanalyse existing interfacial tension data, observe trends across literature data, and detect existing gaps or particularly promising approaches.

Sridharan et al. introduce Artificial Intelligence (AI) and Machine learning (ML) concepts as tools to unravel colloid and interface science linked problems or questions, utilizing predictive modelling, autonomous experimentation, and accelerated material design. As a specific example, the authors describe how AI models have improved the prediction accuracy of physical properties such as interfacial tension, critical micelle concentration, foam stability, or complex structure–function relationships. In particular, integrated generative AI approaches support the design of new surfactants and emulsifiers. The future of AI in colloid and interface science depends on overcoming critical data and integration challenges, many of which are already being addressed in other scientific domains.

Wong et al. describe Machine learning (ML) as a novel tool for advancing the understanding of the behaviour of new colloidal food systems and their production processes whilst maintaining sensory quality and shelf-life. Traditional physics-based models struggle with the multi-scale complexity of food colloids. In this article it is shown how ML is applied to enhance colloidal stability and rheological properties, to monitor microstructures or forecast gel strength. ML-driven approaches can also be used to reduce time-consuming experimental work and to accelerate product innovation. So, according to the authors, ML is a powerful tool allowing to accelerate research and product development of colloidal food products.

The last paper of this series is written by **O'Donoghue & McBratney.** It deals with the topic of Regenerative Agriculture, i.e., an alternative means of producing food that may have lower environmental and/or social impacts. Regenerative agriculture has recently received significant attention from producers, retailers, researchers, and consumers, as well as politicians and the mainstream media, since it offers a response to the pre-eminent paradox of our food system: how to feed the world without eroding the ecological capacity that makes food production possible? The authors state that reorienting farming systems towards ecology and long-term productivity requires more than on-farm changes only. It requires frameworks and infrastructure capable of connecting ecological performance to food quality and market value. This places food science at the centre of the transition.

[1] Plant-based retail market overview | GFI (2024); https://gfi.org/marketresearch/