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Features of water/water emulsions stabilized by particles

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Emulsions are widely used in various applications like cosmetics, food... Indeed, mixing liquids or polymers is a well-known method to obtain new materials with combined and improved properties. The latter, are determined not only by those of the individual constituents, but also by the morphology that results from the combination of phase separation and interfacial properties especially when they are loaded with particles. Since the pioneering work of Pickering and Ramsden, it is well-known that particles can be very efficient stabilizers of emulsions, blends, and foams. Even centimetre size droplets can be stabilized by an adsorbed particle layer, which shows that the underlying stabilizing mechanism differs between systems stabilized with relatively large particles and with molecular surfactants. This talk will review interesting features of these particle-stabilized, so-called Pickering, emulsions by showing their structural and rheological properties. In particular water/water emulsions can be stabilized by particles and form a new class of stable emulsions making them potential candidates for food products.

Assembly of plant storage proteins: role of intrinsic disorder and charge anisotropy.

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Increasing plant protein content in human diet constitutes a world challenge to meet protein needs of the growing world population. However, the assembly properties of such proteins are poorly understood as compared to their dietary animal counterparts. This limits their use as ingredients in food matrices. Most of plant proteins are storage proteins which are synthesized in seed and have to be efficiently stored and dehydrated during seed development. The overall objective of our research activities is to investigate the driving force of plant storage proteins assembly and the influence of their primary role of storage on their structure and functionality. Through this talk, we will first show using computational predictors that amino-acid sequences of plant proteins are predicted to be more disordered than globular animal proteins such as whey or egg proteins. Looking in more details in plant protein sequences reveals that most of them contain low complexity regions comprising polar and/or charged amino acids which are mostly predicted disordered. Then, we will discuss how protein flexibility as well as charge anisotropy can affect the assembly of protein-polysaccharide and protein-protein. We will compare two globular proteins: lysozyme, an egg-white protein, and napin, a rapeseed protein. Lysozyme and napin are very similar in terms of molecular weight and charge density but differ in their surface charge distribution as well as in their intrinsic flexibility. Finally, we will discuss how the use of model polypeptides can help to unravel the role of intrinsic disorder in plant protein self-assembly.

Oleogels in complex composite samples

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Sitosterol and oryzanol self-assemble to form very firm gels in a range of organic solvents. [1] Unfortunately, due to the formation of sitosterol hydrate crystals, these gels are unstable in the presence of water, prohibiting the dispersal of water droplets throughout the gel matrix. We demonstrate that by using glycerol as the polar phase rather than water, droplets may be dispersed throughout the oil phase without disrupting the self-assembly of the gel.[2] As increasing volumes of water are added to the glycerol, the G_0 values decrease. This can be correlated to both a drop in water activity, and also the stability of the fibrils in the presence of glycerol compared to water, as elucidated by molecular dynamics simulations. At high glycerol loadings, multiple emulsions are observed to form.

We further demonstrate that by mixing the phytosterol-ester oryzanol with lecithin in an organic solvent, both components may be dispersed at much higher concentrations than they may be individually. [3] Dynamic light scattering and molecular dynamics simulations show that the mechanism for this is the formation of mixed micelles. Infrared spectroscopy and simulations suggest that these micelles are formed due in part to hydrogen bonding of the phosphate of the lecithin head-group, and the phenol group of the oryzanol. Rheology shows that by mixing these materials at an equimolar ratio, highly viscous suspensions are created. Furthermore, by adding water to these samples, a solid-like gel may be formed which offers mechanical properties close to those desired for a margarine type spread, whilst still solubilizing the oryzanol.

References

- [1] Matheson, A. B., Koutsos, V., Dalkas, G., Euston, S., & Clegg, P. (2017). Microstructure of β -Sitosterol: γ -Oryzanol Edible Organogels. *Langmuir*, 33(18), 4537–4542.
- [2] Matheson, A., Dalkas, G., Mears, R., Euston, S. R., & Clegg, P. S. (2018). Stable emulsions of droplets in a solid edible organogel matrix. *Soft Matter*, 14(11), 2044–2051.
- [3] Matheson, A. B., Dalkas, G., Gromov, A., Euston, S. R., & Clegg, P. S. (2017). The development of phytosterol-lecithin mixed micelles and organogels. *Food & Function*, 8(12), 4547–4554.

Structure and Dynamics of Polymer Composites and Gels: A Simulation Perspective

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Polymers or biopolymers are not only present in daily-life materials such as food, packaging or paints, but also in living organisms (plant cell wall, cytoplasm, extracellular matrix). The mechanical properties of these materials are strongly influenced by the structure and the dynamics of the polymers they are made of. In this context large-scale numerical simulations of the behaviour of the polymers can give insight into their collective properties at the nanoscopic scale and hence help to decipher the influence of the latter on the macroscopic properties of materials.

In this presentation we introduce the use of simulations of polymer systems at a coarse-grained level, and give an overview of the structural and dynamical properties which can be computed from this kind of approach, and discuss how they can be related to the macroscopic properties.

This is illustrated on two systems. The first one deals with nanoparticle-polymer composites: The simulations help to reveal the influence of nanoparticle size and volume fraction on the structure and dynamics of the polymers [1]. In the second example we consider a polymer solution which turns into a polymer gel due to the action of mobile catalysts and we show the implications of this process on the structuring of the resulting gel and on the time scales relevant to this sol-gel transition [2].

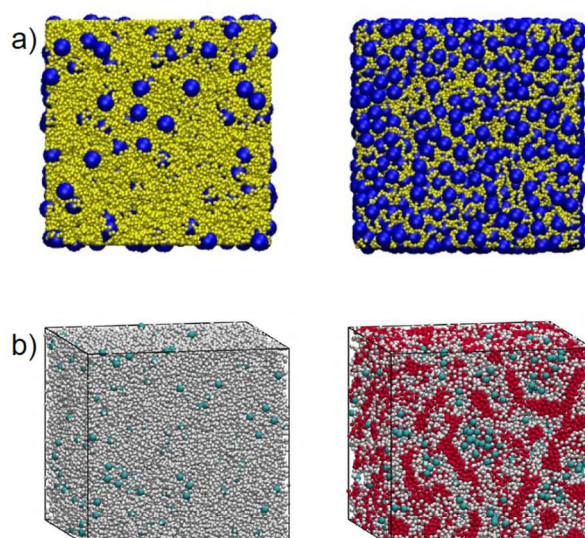


Figure 1: a) Polymers (chains of yellow monomers) and nanoparticles (blue) at low (left) and high (right) nanoparticle volume fractions [1]; b) A solution of polymers (left) transforms into a polymer gel (right) due to the conversion by catalysts (blue) of repulsive monomers (white) into attractive monomers (red) [2].

References

- [1] Sorichetti V., Hugouvieux V., Kob W. Structure and Dynamics of a Polymer–Nanoparticle Composite: Effect of Nanoparticle Size and Volume Fraction. *Macromolecules* **2018** 51 (14), 5375-5391
- [2] Hugouvieux V., Kob W. Structuring polymer gels via catalytic reactions. *Soft Matter* **2017** 13(46), 8706-8716.

Recent developments in the field of edible double emulsions

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Water-in-Oil-in-Water ($W_1/O/W_2$) emulsions are made of oil globules (O) dispersed in an aqueous phase (W_2), with the globules themselves containing aqueous droplets (W_1). Generally, their stability is ensured by two surface-active species of opposite solubility (oil-soluble and water-soluble). As food products, these materials have many technological assets. Due to their compartmented structure, they can be used to encapsulate active species in the inner droplets and to control their delivery towards the external phase. They may also allow reducing the caloric intake without compromising taste. Fat is partially replaced by an aqueous phase, while tricking our tongue into thinking we are still eating a product with a full fat, creamy flavor. Despite these advantages, only a few commercial products based on double emulsions have been developed so far. The main difficulty with double emulsions is the mastering of their complex kinetic evolution. This complexity is naturally arising from their internal dynamics which are due to the liquid state of the components. However, their behavior is now quite well understood and significant advances have been made to improve their formulation and functional properties. Once fabricated they can become trapped in deep metastable states, allowing storage for several months with minimal leakage of the encapsulated species. Because they are made of soft matter, essentially liquids, there are many possible strategies to disassemble the compartmented structure and to trigger delivery on demand.

The purpose of this lecture is to emphasize recent developments. This will be illustrated by two examples:

- A gelation process based on the osmotically driven water flux between the two aqueous compartments of double emulsions [1]. We first prepare fluid water-in-oil-in-water ($W_1/O/W_2$) double emulsions whose external aqueous phase contains hydrocolloids and/or proteins at moderate concentration. The initial osmotic pressure in the innermost droplets is considerably larger than that in the external phase. An inward water transfer thus occurs in order to restore osmotic equilibrium. In the initial state, the globules are large and so the transfer is slow because of the limited exchange surface area. The emulsions are then submitted to a short and intense shear that provokes globule breakup, in order to increase the rate of water diffusion. As a consequence, the initially fluid materials undergo a sudden rheological transition. During that process, the hydrocolloids and/or proteins are concentrated in the continuous phase until a point that a gel is formed. The proposed approach demonstrates a simple, yet versatile and adaptable solution for making texturized emulsions with reduced fat content and limited amount of hydrocolloids/proteins.
- The design double emulsions devoid of lipophilic surfactant, based on the use of a crystallizable oil and proteins. Simple W_1/O emulsions stabilized solely by fat crystals are first prepared by dispersing the W_1 aqueous phase in a surfactant-less fat phase at a temperature above its melting range, followed by cooling down to trigger bulk fat crystallization. The resulting W_1/O emulsions are arrested systems that are stable against gravitational and colloidal instabilities upon storage. The primary emulsions are in turn dispersed in a highly viscous external aqueous phase containing proteins to obtain $W_1/O/W_2$ emulsions. The resulting materials have enhanced properties compared to conventional double emulsions including i) very slow passive delivery of the encapsulated species, ii) resistance to osmotic stress, iii) resistance to coalescence, and iv) thermo-responsiveness as the double globules could release the inner droplets' content upon warming. We generalize the concept to the preparation of air-in-oil-in-water multiple emulsions.

References

[1] M. Delample, F. Da Silva, F. Leal-Calderon, *Osmotically driven gelation in double emulsions*, Food Hydrocolloids, 38, 11-19 (2014)

Nanoscale Engineering of the Structure and Functionality of Fat and Oleogel Systems

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Fats and oils are extremely useful natural products which are widely used in foods, cosmetics and industrial applications. As the concern for the environment and health grows, consumers are demanding more natural, green and sustainable materials in everyday consumer products. Fats and oils are complex multicomponent mixtures of triacylglycerol molecular species. The nature of these molecular species are a function of both fatty acid composition and distribution within the TAG molecule. The purpose of this talk is to discuss the structure of fats and oils, from constituent TAG molecules to the crystals they form. Upon crystallization, TAG molecules form lamellae (shown in blue), which stack to form a highly asymmetric nanoplatelet with about ~8 TAG lamella (Figure 1)¹. We

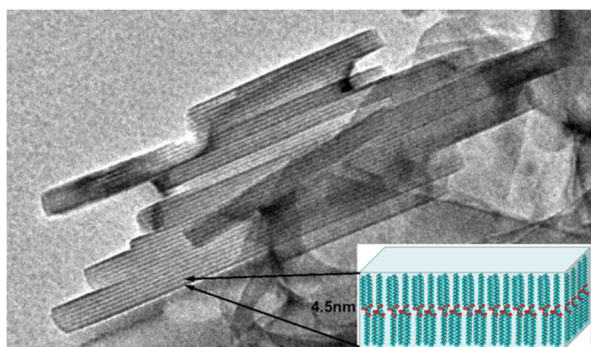


Figure: Cross-sectional view of a TAG nanoplatelet showing epitaxial molecular packing in the [001] direction

have been able to engineer the thickness of these nanoplatelets by using specific surfactants and affecting the surface energy and surface nucleation behavior of TAGs on these crystalline nanoplatelets². These nanoplatelets rapidly aggregate into colloidal structures of differing morphologies and size depending on external fields and concentration, forming networks which are responsible for the binding of oil, water vapour barrier properties, and mechanical properties of the fat. Our work has focused on developing and understanding of the functionality of fats from a structural perspective. Early work focused on the quantification of structure using small deformation rheological techniques. More recent work has focused on the use of scattering methods, in

particular Ultra-Small Angle X-ray Scattering at synchrotron facilities to quantify atomic scale structure to mesoscale structure simultaneously, in a non-destructive fashion³. Increasing public concerns over excessive saturated and *trans* fat intake from manufactured food products has led to the search for alternative strategies to structure liquid oils into semisolid fats without addition of large amounts of unhealthy *trans* and saturated fats. Surfactant-like small molecules have been shown to self-assemble into long fibrils, effectively causing oil gelation at concentrations as low as 0.5%. Phytosterols, ceramides, waxes and 12-hydroxystearic acid have been shown to be effective organogelators. Liquid oils can also be structured by microencapsulation within multilamellar vesicles, with walls composed of monoglyceride hydrates in the alpha-gel state. The surface potential of these monoglyceride vesicles is then adjusted so as to maximize inter-vesicle interactions and the formation of a cellular solid with oil-filled cells. These monoglyceride gels have recently been proven to have excellent functional characteristics in baking applications as well as for omega-3 oil stabilization. High-molecular weight polymers such as ethylcellulose have also been successfully used by our group to gel oil in the absence of water. This development of a polymer-stabilized organogel is very promising since these polymers are widely available and are food-grade. The development of a new way to make fat exploiting the self-assembly properties of food-grade molecules is at hand. A final perspective of future challenges will be offered.

References

- [1] Acevedo, N. and Marangoni, A.G. 2010. Characterization of the nanoscale in triglyceride crystal networks. *Crystal Growth and Design* 10: 3327-3333.
- [2] Ramel, P., Co, E.D., Acevedo, N.A. and Marangoni, A.G. 2016. Nanoscale structure and functionality of fats. *Progress in Lipid Research* 64: 231-242
- [3] Pink, D.A., Quinn, B., Peyronel, F. and Marangoni, A.G. 2013. Edible Oil Structures at Low and Intermediate Concentrations: I. Modelling, Computer Simulation and Predictions for X-ray Scattering. *J. Applied Physics* 114: 234901.

Tackling the question of specific interactions in a complex blend of proteins

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Natural protein sources often display a huge complexity, being composed of a blend of polypeptides of various molecular weight, pHi and charge density. Gluten, the proteins extracted from wheat flour is one of such. Gluten is widely used for its viscoelastic properties as an improver of cereal products (bread, pastry, etc.). It is composed of two classes of proteins, named gliadin and glutenin, similar in their amounts in glutamine (30%) and proline (10%). The more than 25 different polypeptides belonging to the gliadin class are hard to fractionate into individual components because of high redundancy in the primary sequences. Glutenin are in the form of polymers made from several distinct polypeptides concatenated through inter-chain disulfide bonds. Their molecular weights are evenly distributed from 100 kg/mol to 7,000 kg/mol.

While it is well established that gliadin confers viscosity to gluten whereas glutenin polymers are at the origin of its elastic resistance, the interactions existing between both classes of gluten protein remain unknown. We previously showed by SLS and multi-angle DLS that gluten proteins suspended in ethanol/water (50/50, v/v), a theta solvent, includes large proteins assemblies (26,000 kg/mol, Rh 100-128 nm) displaying an internal dynamic. To get a better insight of the composition of those assemblies, we combined biochemical and physicochemical approaches. On the one hand, gluten proteins suspended in ethanol/water were fractionated by Asymmetrical- Flow-Field-Flow Fractionation (A4F) coupled to UV, SLS and QELS detectors. On the other hand, gluten proteins were partitioned by liquid-phase decomposition in respect with temperature. Protein composition of partitioned phases and eluting fractions recovered from A4F were characterized by size-exclusion chromatography. Consistent results were obtained demonstrating a specific interaction between omega-gliadin and glutenin polymers. The work illustrates how a detailed analysis of the phase behavior of a complex blend of proteins may reveal their supramolecular assembly states.

Global Small-Angle X-ray Scattering Data Analysis of Triacylglycerols in the Molten State

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The study of triacylglycerols (TAGs) in their molten state is of fundamental importance for a deeper understanding of TAG-crystallization processes, being highly relevant for both, manufacturing and medical applications. Whilst different models have been proposed to explain the nanostructured nature of the fluid state of TAGs, none of them are fully satisfactory. In this paper, we propose a new model consisting of positionally uncorrelated lamellar TAG-assemblies embedded in an isotropic medium, that assist as pre-nucleating structures. This model was validated by applying a novel global fitting method, resulting in excellent agreement with the small angle X-ray scattering data. Deeper analysis of the scattering patterns at different temperatures, both in cooling and heating direction, allowed us further to detect crystalline traces of TAGs even after heating to 40 °C, and record on cooling the onset of crystallization at 30-25 °C. The application of the presented novel model not only explains the outstandingly structured fluid of molten TAGs, but also lays the basis for analysing first crystallization steps in greater detail, which is outlined in our follow-up study 'Global Small-Angle X-ray Scattering Data Analysis of Triacylglycerols in the α -Phase (Part II)' [1].

References

- [1] M. Rappolt, A. Sadeghpour, M. Ladd Parada, J. Vieira and M. Povey: Global Small-Angle X-ray Scattering Data Analysis of Triacylglycerols in the Molten State (Part I) & Global Small-Angle X-ray Scattering Data Analysis of Triacylglycerols in the α -Phase (Part II). Under Review in J Phys Chem 2018.

Functional protein-based colloids for controlling structure and stability of food

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Native globular whey proteins are sensitive to heat treatment above their denaturation temperature. Heating induces molecular changes, leading to an activated non-native protein form that is able to self-aggregate. Depending on the processing conditions (pH, ionic strength, protein concentration, heating temperature and heating time), various types of protein aggregates are obtained.¹

In this talk, we will describe whey protein microgels (WPM), a peculiar type of aggregate obtained upon heat treatment slightly above the IEP of whey proteins.² The WPM are characterized by fairly spherical shape, narrow polydispersity, high surface charge density and particle size ranging from 200 to 400 nm. These features confer milky appearance and colloidal stability upon storage to WPM dispersions. The internal structure of WPM is maintained by hydrophobic/hydrogen bonds and disulfide bridges. This allows high physical and chemical stability of these new ingredients in various subsequent food processes.³

We will show how WPM can be concentrated using microfiltration in order to reach high protein contents while keeping the system liquid. The thermal stability of WPM in presence of salts as well as their use as whitening agent in low fat coffee creamers will be presented.⁴ Whey protein microgels can also be used to stabilize Pickering-type of emulsions close to their IEP.⁵ Finally, we will discuss the use of these colloids as texture modulators in whey protein acid gels.⁶

References

- [1] Nicolai T., Britten M. & Schmitt C. (2011). β -lactoglobulin and WPI aggregates: Formation, structure and applications. *Food Hydrocolloids*, 25, 8, 1945-1962.
- [2] Schmitt C., Vuillomenet A.-M., Bovay C., Rouvet M., Bovetto L., Barbar R. & Sanchez C. (2009). Multi-scale characterization of individualized β -lactoglobulin microgels formed upon heat treatment in narrow pH conditions. *Langmuir*, 25, 14, 7899-7909.
- [3] Schmitt C., Moitzi C., Bovay C., Bovetto L., Donato L., Leser M. E., Stradner A. & Schurtenberger P. (2010). Internal structure and colloidal behaviour of covalent whey protein microgels obtained by heat treatment. *Soft Matter*, 6, 19, 4876-4884.
- [4] Bovetto L., Schmitt C., Robin F., Pouzot M. & Lagarrigue S. (2007). Whey protein micelles. World patent application WO2007110411 A2.
- [5] Destribats M., Rouvet M., Gehin-Delval C., Schmitt C. & Binks B.P. (2014). Emulsions stabilised by whey protein microgel particles: towards food-grade Pickering emulsions. *Soft Matter*, 10, 36, 6941-6954.
- [6] Donato L., Kolodziejczyk E. & Rouvet M. (2011). Mixtures of whey protein microgels and soluble aggregates as building blocks to control rheology and structure of acid induced cold-set gels. *Food Hydrocolloids*, 25, 4, 734-742.

Food oral processing: From structure to behaviour, perception and pleasure

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Food oral processing as the bridge between transformation of food structure during consumption, eating behaviour, sensory perception and food acceptability has gained enormous interest in the last decades. An overview of the interplay between food structure, oral processing and eating behaviour, sensory perception and hedonic evaluation of foods is provided comparing different consumer groups. To design foods which are targeted to different consumer groups, food structures and its oral breakdown properties should be matched with preferred behaviour to optimize pleasure upon consumption.

It is demonstrated that food oral processing depends on both food properties and consumer characteristics. Consumers strongly adapt oral processing behaviour with respect to bite size, consumption time, and eating rate to rheological and mechanical properties of liquid, semi-solid and solid foods. Liking and familiarity influence oral processing behaviour, but by a considerable lower degree than rheological and mechanical properties. Correlations between instrumental texture properties of solid foods and oral processing behaviour provide guidance on parameters that are likely to produce 'faster' and 'slower' versions of foods. This demonstrates how food texture modifications can be applied to moderate eating rate and energy intake.

It is shown how age, gender, and ethnicity affect oral processing behaviour of liquid, semi-solid and solid foods differently. Consumer groups adapt eating rate in different ways by modifying bite size, consumption time or both. Parameters describing oral physiology explain differences in oral processing behaviour between groups only to a limited extent. Other oral physiological and cultural factors might contribute more to differences in oral processing behaviour between groups. While age, gender and ethnicity can influence oral behaviour, bolus properties do not necessarily differ between groups suggesting that although oral behaviour may vary somewhat between groups, similar bolus properties can be reached. However, large differences in oral behaviour between groups (fast and slow eaters) lead to considerable differences in bolus properties leading to differences in sensory perception and food intake.

Many foods are composed of multiple components with considerably different mechanical properties on micro- or macroscopic length scales, for example breads with toppings or soups with vegetable pieces. Mechanical contrast between food components can lead to contrasting texture sensations, which can enhance palatability and reduce energy intake. The influence of mechanical contrast caused by inhomogeneity in food structure at different length scales on oral processing behaviour, sensory perception and palatability is discussed. Combining food components with contrasting mechanical properties at different length scales allows to control oral processing behaviour, bolus properties and determines texture perception and palatability.

Protein Gels and Glasses

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Gels and glasses represent important soft matter classes in today's food science and technology. Currently the vast majority of food gels is based on energy-intensive processes using heat and pressure treatments. On the other hand, colloid scientists have studied various liquid-solid transitions such as dynamical arrest, jamming and gelation intensively during the last decade, and the thus gained insight could potentially have a considerable importance for food science and the possibility to create food gels through different novel routes [1]. Here we will present first a short summary of our current understanding of colloidal gels and glasses, and introduce key concepts such as arrested spinodal decomposition or cluster formation and arrest in colloids with competing attractive and repulsive interactions. We will then demonstrate that such arrest scenarios can also be found for proteins and food colloids, and show how we can use a combination of scattering methods [1-6] (small-angle neutron and x-ray scattering, diffusing wave spectroscopy), confocal microscopy [1,5,6] and micro- [7] and macrorheology [1,5,6] to characterize the structural and dynamic properties of these complex liquids and solids at all relevant length and time scales.

References

- [1] Gibaud T., Mahmoudi N., Oberdisse J., Lindner P., Pedersen J.S., Oliveira C.L.P., Stradner A., Schurtenberger P. "New routes to food gels and glasses" *Faraday Discussions* **2012**, 158, 267
- [2] Van Gruijthuijsen K., Tuinier R., Brader J., Stradner A. "Phase behaviour of colloids with short-range repulsions plus nonadsorbing polymer chains" *Soft Matter* **2013**, 9, 9977
- [3] Van Gruijthuijsen K., Obiols-Rabasa M., Schurtenberger P., Bouwman W.G., Stradner A. "The extended law of corresponding states when attractions meet repulsions" *Soft Matter* **2018**, 14, 3704-3715
- [4] Xie F., Turesson M., Woodward C.E., Van Gruijthuijsen K., Stradner A., Forsman J. "Theoretical predictions of structures in dispersions containing charged colloidal particles and non-adsorbing polymers" *Phys. Chem. Chem. Phys.* **2016**, 18, 11422-11434
- [5] Mahmoudi N., Stradner A. "Making food protein gels via an arrested spinodal decomposition" *J. Phys. Chem. B* **2015**, 119, 15522-15529
- [6] Mahmoudi N., Stradner A. "Structural arrest and dynamic localization in biocolloidal gels" *Soft Matter* **2017**, 13, 4629-4635
- [7] Garting T., Stradner A. "Optical Microrheology of Protein Solutions using Tailored Nanoparticles" *Small* **2018**, 1801548

Protein-fiber mixed systems to innovate in food and culinary applications

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Protein and fiber are two food constituents of growing interest to health-conscious consumers. In recent years, the molecular interactions between these two macromolecules and the behavior of mixed systems have received increasing research attention in order to design food product with extended applications. Indeed, protein and some constituents of fiber, especially pectin, can form complexes at acidic pH, mostly through electrostatic interactions between these two oppositely charged macromolecules. These complexes could improve the functionality of foods. However, studies on these complexes in real food conditions are missing and their utilization in culinary applications is inexistent. Approaches allowing complex formation using purified and crude fiber sources to develop functional ingredients will be presented. First, water (WAC) and oil (OAC) absorption capacity of plant proteins (soy, pea) and sugar beet pectin complexes were evaluated. The effect on WAC is source dependent as complexes produced with one soy protein source showed a 24% increase (ratio 1:1) in comparison to individual biopolymers while the pea protein showed a reduction (25%). OAC of individual ingredients is increased (from 36-60%) after complex formation. Secondly, complex formation between proteins and blueberry puree was studied. After the addition of a whey protein isolate (WPI) into purees, the soluble pectin and protein contents and the viscosity of the resulting mixtures were determined. The decrease in the solubility of pectin and proteins showed the formation of protein-pectin complexes by electrostatic interactions at pH 3.5, contributing to increase the mixture viscosity. This mixture was also incorporated in a smoothie. The interactions between blueberry pectin of a puree and whey proteins allowed to design a novel functional ingredient that may be used to formulate high-fiber and high-protein beverages. Finally, the potential of using vegetable puree and some fractions for culinary innovations will be presented using parsnip as a model. The intelligent association between protein and fiber offer many new opportunities to add functional and nutritional values into processed foods and culinary applications.