3rd Edible Soft Matter Conference

7 – 10 July 2025

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X-ray micro-computed tomography (micro-CT) of edible mushrooms, a tool to unravel spoilage mechanisms

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Keywords: Mushrooms, micro-computed tomography, microstructure, solid foam, food waste

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Abstract:

Structural breakdown plays a significant role in the onset of food deterioration reactions. Assessing food structural integrity is difficult due to the invasiveness and destructiveness of extant techniques. These challenges can be partially overcome by using micro-CT. Mushrooms exhibit a porous structure reminiscent of solid foams that differ within parts and among mushroom types. Also, their shelf life is short. Thus, mushrooms constitute an ideal case study to elucidate the role of structure in food spoilage.

Oyster (OM) and white (WM) mushrooms were purchased locally and stored at 4 and 12°C, RH=92%. Size, colour and derived indexes were assessed using image analysis and colorimetry at set intervals. Specimens at different storage intervals were fixated (10% formalin), chemically dehydrated (25-100% ethanol), and critical point dried (Autosamdri®-931, Tousimis). High-resolution micro-tomographs of the specimens were collected at the BMIT-BM 05B1-1 line (Canadian Light Source Synchrotron). Renderings were reconstructed using UFO-KIT software, and porosity and tortuosity were estimated using Avizo.

In OM, high initial porosity (0.64) and low tortuosity (1.14) facilitate gas exchange, leading to dehydration, the progress of oxidative reactions and short shelf life. Microtomographs of WH stored at 4°C show structural fissures and collapsing of interstitial spaces by the end of storage. Decreased porosity (0.54 vs. 0.36) and tortuosity (1.43 vs. 1.19) in WM during storage suggest the collapse of structural elements in all tissues, leading to extensive discoloration (colour difference ~30 AU initial vs. final). This study provides valuable insights into the internal structure and the relevance of their assessment.

Effect of fat source on the microstructure and rheology of plant-based protein emulsions for meat analogue applications

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Keywords: plant-based proteins, emulsions, microstructure, rheology, meat analogues

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Abstract (max 250 words) :

Due to environmental and health concerns, demand for meat alternatives is rising, increasing the interest in plant proteins and meat analogues. Fat plays an important role influencing texture and mouthfeel in meat analogues. This study investigates the effect of different fat sources on the microstructure, rheology and juiciness of oil-in-water emulsions used in plant-based patties. Emulsions were prepared using soy protein with rapeseed oil, beef tallow, palm oil, and palm olein and were characterised using Coherent Anti-Stokes Raman Scattering (CARS) microscopy and rheology. These emulsions were then incorporated into soy-based patties, which were analysed uncooked by CARS microscopy.

Microstructural analysis showed that rapeseed oil emulsions had significantly smaller and round fat particles, whereas other fat sources formed larger, irregularly shaped, and agglomerated fat microparticles. Lipidic area analysis indicated that rapeseed oil and palm olein emulsions had the highest fat area, while beef tallow and palm oil exhibited lower values. Rheological results showed that all emulsions exhibited predominantly elastic (solid-like) behavior. Beef tallow emulsions demonstrated the highest gel strength but were more sensitive to temperature increases, while palm olein emulsions showed higher resistance to deformations.

After incorporation into patties, microstructural analysis revealed that mixing altered fat particle morphology, leading to irregular and agglomerated fat structures across all formulations. Despite retaining a high number of fat microparticles, patties with rapeseed oil emulsions exhibited morphology similar to the patties prepared with other fat emulsions.

These findings highlight the impact of fat source on emulsion characteristics and their role in optimizing plant-based meat formulations.

Molecular dynamics simulations of dairy systems: one forcefield for both globular and intrinsically disordered dairy proteins

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Keywords : Dairy proteins, caseins, molecular dynamics, forcefields, protein interactions

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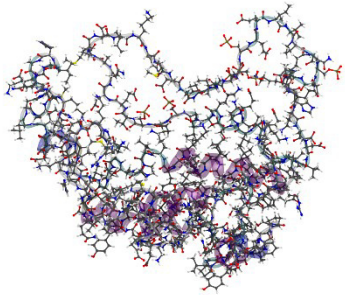
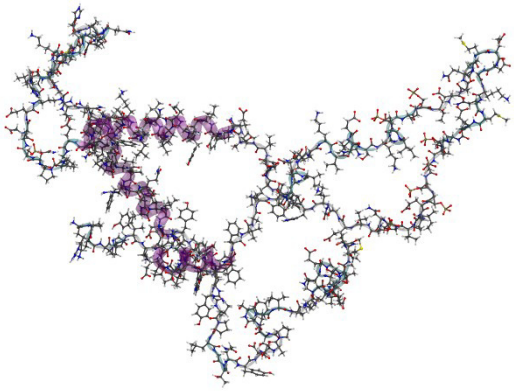
Abstract :

The structure and dynamics of dairy protein systems are governed by their molecular-scale interactions. Molecular dynamics (MD) simulations serve as a robust method for elucidating these interactions, and with the advancement of computational capabilities, it is now feasible to simulate at length- and time-scales relevant to dairy systems. While globular dairy proteins have been widely studied via MD over the past few decades [1,2,3], simulating caseins—which are intrinsically disordered proteins (IDPs)—remains challenging. This difficulty stems from the absence of crystal structures for caseins and the propensity of standard all-atom forcefields (such as AMBER) to produce overly compact structures. In this study, we aim to identify an all-atom forcefield suitable for simulating a spectrum of dairy proteins, ranging from globular protein to IDPs. Our findings indicate that conventional forcefields like AMBER simulate caseins that are too compact; however, by employing the method of scaling protein-water interactions [4], we achieve well-solvated caseins using a variant of the AMBER12 forcefield. Additionally, this forcefield maintains the secondary and tertiary structures of globular proteins such as β-lactoglobulin and α-lactalbumin, with slight increases in their dynamics. Crucially, our results indicate that a single forcefield can accommodate both globular and intrinsically disordered dairy proteins. These results pave the way for utilizing molecular dynamics simulations to understand the interactions responsible for the behaviour of complex dairy systems.

αs1-casein



AMBER12



AMBER12 (protein-water interaction scaled)

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Non-Aqueous Food-Grade Droplets Under AC Electrohydrodynamic Effects

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Keywords (5 max): Electrohydrodynamic Stabilization, Food grade Non-Aqueous Emulsions, AC Electric Fields.

Abstract: Oil-in-oil (O/O) emulsions are a type of non-aqueous emulsion used in drug delivery, cosmetics, lubricants, and electrical devices[1]. The absence of water provides advantages, such as preventing water-induced by-products and enabling electrohydrodynamically (EHD) assisted stabilization due to low electrical conductivity[2]. In this study, we investigate an edible O/O emulsion system consisting of an edible oil phase and an edible polar organic solvent. We demonstrate that this system can also be stabilized using EHD. Specifically, we examine the effects of AC EHD on single and small groups of droplets composed of a propylene glycol–ethanol mixture within a continuous medium-chain triglyceride (MCT) phase. Food-grade encapsulated fat crystals*[3] or ethylcellulose (EC) particles are used as stabilizers. In the future, we will scale up to study emulsions with multiple droplets.

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* Registered trademark

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Development of image analysis methods to characterize the fibrous structure of High-Moisture Extrusion-Cooking extrudates

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Keywords (5 max): Meat analogues, X-Ray Tomography, Anisotropy, Microscopy, Wheat gluten

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Abstract:

The fibrous texture of meat analogues produced by High Moisture Extrusion-Cooking is not easy to quantify, as fibers cannot be isolated. Yet, this is necessary to better understand this process and valorize different types of plant proteins. Some microscopic observations may provide a view of the fibers at the microscale, but the sample preparation may deteriorate the microstructure. X-ray tomography is another possibility to assess the microstructure without invading the sample but requires costly equipment. Moreover, these microscale observation technics do not reflect the fibrous structure visible by the consumer at macroscale. Up to now, the anisotropy index is the most common parameter used to quantify the fibrousness of extrudate but does not provide any information on the number and shape of the fibers.

For these reasons, we developed a method based on macroscale image analysis of the lamellarity and tearing strands of the extrudate, visible when it is opened in two parts. These properties have been compared to the common analyzes, *i.e.*, optical microscopy, X-ray tomography and anisotropy index, and a decision tree has been built. This comparison has been conducted on extrudates made from a model mix of wheat gluten and soy concentrate.

Links have been raised between the macroscale and microscale observations in terms of fibrous structure, and led to more appropriate “tearing strands” designation instead of “fibers”, which might come from the pore walls inside the extrudates. The results led to the hypothesis that the resistance of these strands will account for the quality of the fibration.

Investigating the structuring mechanisms of 3D-printed systems made from cereal, pseudo-cereal and legume flours

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Keywords (5 max): 3D printing, rheology, printing quality

Abstract : (250 Words Max)

3D food printing is a technology that is being increasingly studied, in particular for the development of personalized nutrition products. To date, there remains limited understanding regarding how the rheological and structural properties of the printed matrix influence its ability to be extruded, shaped, and to retain its shape after printing. The aim of this study is to explore how the composition in starch, fibers and proteins of six different types of flour affects the rheological and structural properties of flour-based matrices, and consequently, their printing quality. The flours selected—wheat, rye, rice, kidney bean, lupin, and chia seed flours—were used to formulate matrices with a constant dry matter content, made through mechanical and thermomechanical processing. These matrices were characterized via a multiscale approach. The structure of the matrices was observed using confocal microscopy, their rheological properties were determined using texturometry and rheometry and a new image analysis protocol was developed in order to characterise the printed product. The starch gelatinization degree of the doughs was controlled with Differential Scanning Calorimetry (DSC). We found a relationship between the biochemical composition of the flours, the rheological properties of the matrices and their printing quality. More specifically, we highlighted the role of starch content, hydration level of the flours at room temperature (in relation to their water holding capacity) and dough stickiness in the printing quality of the matrices. Based on these findings, we formulated hypotheses regarding the structuring mechanisms of the matrices and gained insights to guide further investigation.

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249 words

Heat-induced gelation of rapeseed oil-in-water emulsion

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Keywords : Cruciferin; napin; emulsion-gel; mixture; rheology

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Abstract : This study explores the potential of rapeseed protein isolate (RPI) as a functional ingredient in the food industry. Traditionally, rapeseed has been cultivated for its oil, with the by-product often used for animal feed. However, this research focuses on valorizing rapeseed protein, which is isolated, pre-treated, and purified to develop heat-induced emulsion gels with potential food applications. The study examines how heat treatment, pH, ionic strength, oil content and protein concentration affect the rheological behavior and microstructure of rapeseed emulsion gels. The presence of emulsified oil in the RPI system facilitated the formation of self-supporting gels, which were homogeneous with reduced syneresis compared to gels without oil. The storage modulus (G') increased with higher rapeseed oil (RO) content and protein concentration. Specifically, adding 10% RO reinforced the elastic modulus by a factor of 10, regardless of protein concentration, and a sharp increase in G' was observed with 20-30% RO. Between 30% and 50% RO, this effect plateaued. CLSM images showed that oil droplets were encapsulated by rapeseed protein microgels. The study found minimal effects of pH (except at ≤ pH 5), ionic strength, and protein concentration on the rheology and microstructure of the gels. Overall, the study demonstrates the potential of rapeseed emulsion gels as fat replacers and for encapsulation, offering new possibilities in food product formulation, particularly for individuals with dysphagia.

Egg-Free Light Mayonnaise Stabilized by Lupin Protein–Proanthocyanidin Complexes: Rheological, Tribological, and *In Vitro* Digestibility Studies

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Keywords : Digestibility, Rheology, Tribology, Plant protein

Abstract : Oil-in-water (O/W) emulsions stabilized by plant protein–phenolic compound complexes offer significant potential for creating light egg-free mayonnaise. In this study, complexes of lupin protein and grape seed extract were used as stabilizers to develop mayonnaise-like emulsions. The effects of acetic acid (pH), sodium chloride (NaCl), and sucrose — key ingredients in commercial mayonnaise — were investigated. Rheological and tribological analyses were performed to assess the influence of these ingredients on the bulk and surface properties of the emulsions. Based on droplet size distribution, viscosity, thixotropic recovery, and microstructure analysis, an optimal formulation containing 350 mmol NaCl and 4 wt% sucrose was identified, yielding an egg-free emulsion with physicochemical properties comparable to commercial light mayonnaise. Additionally, the produced emulsion exhibited *in vitro* digestibility similar to the commercial product. The bioaccessibility of phenolic compounds from grape seed extract was also confirmed, highlighting the potential of lupin protein–phenolic compound complexes for developing functional egg-free mayonnaise alternatives.

Cyclic Formulation and Reuse of Raw Materials : Impact on Foam Properties and Material Evolution

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Aim:

Oryza Sativa Rice Bran Wax (RBW) is a clean-label byproduct of rice oil production. Previous works on rice bran wax focused on the preparation of oleogels and W/O emulsions, requiring dispersing agents as well as heating processes *(Nutter, J. et al., 2023 ; Pandolsook, S. et al., 2017)*. A recent study* has shown that micronized RBW can stabilize aqueous foams (RBWF) through a Pickering effect, enhanced by the loading of the continuous phase and the formation of bridge-like structures. Additionally, it has been shown that these foams can be recycled by recovering RBW from the dried foam, allowing the formulation of new foams using the recycled raw material. Based on the observation that RBW powder became increasingly smooth over successive cycles, this study aimed to investigate the changes RBW undergoes during recycling and to establish their relationship with foaming capacity and foam structure.

Method:

The same formulation protocol was applied throughout the study: 5 minutes using a single air-gap rotor-stator at 10,000 rpm. The same RBW was used over three successive cycles. Due to the slight material loss occurring throughout the cycles, it was necessary to prepare three 150 g beakers of material to obtain one final beaker in the last cycle. The powders obtained from each cycle were chemically characterized using the Dumas method and observed under SEM to determine their size distribution and morphology. RBWF from different cycles were characterized using a multiscale approach to characterize both their macroscopic properties and the microscopic architecture and organization of their structure.

Results:

1. RBW can be successfully reused to produce and stabilize Pickering-stabilized aqueous foams.

2. RBW particles undergo chemical changes, as a slight decrease in carbon content was measured across the cycles. SEM observations also revealed morphological changes, with particles becoming more rounded and slightly smaller (1 to 2 µm).

3. RBWF exhibited significant differences across the cycles, with firmness decreasing dramatically—10 to 20 times—between the first and third cycle. Apparent density, in contrast, showed a significant increase.

4. CLSM and X-ray microtomography analyses at each cycle revealed that, over successive cycles, fewer structuring elements, such as bridge-like structures and dense particle layers at the interface, were observed. Additionally, a decrease in air volume fraction was observed, which was used to quantify the difference between cycles 1 and 3 in terms of overrun (−25%) and porosity (−0.05).

5. While RBW can be reused, its ability to stabilize foams is progressively altered. The mixing process with the rotor-stator appears to “wash” the particles, modifying their geometry and removing certain compounds from the crystals, two parameters that are likely to promote aggregation and the formation of structuring networks.

Conclusion:

This study provided a better understanding of the structural parameters governing aqueous foams stabilized by fatty acid crystals, opening new perspectives for the design of such systems with an ultra-simple formulation and stabilization through clean-label particles. The differences in structure and properties between systems at different cycles could also be leveraged as a source of matrices suited for various products and applications.

* *Paper to be submitted soon*

Lysozyme/Alginate Interaction: structural and thermodynamic insights through ITC and SAXS

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Keywords (5 max): Aggregation, Complex coacervation, ionic strength, ITC, SAXS

Abstract: The liquid-liquid phase separation (LLPS) process called coacervation requires net charge neutralization between two oppositely charged macromolecules while precipitation/aggregation involves strong intimate contact between the macromolecules. Coacervation and aggregation (Liquid-solid phase separation, LSPS) are thus intrinsically different phenomena, responsive to different factors, but their simultaneity (for example with changing pH or ionic strength) may be confused with transitions from one state to another. The present study explores the interplay between coacervation and aggregation in lysozyme (LYS) / alginate (ALG) mixtures, focusing on the impact of ionic strength. The ionic strength-dependent interaction was probed using Isothermal Titration Calorimetry (ITC) while the structure of the complexes was analyzed using Small-Angle X-ray Scattering (SAXS). Our results confirm that low salt concentrations lead to the formation of aggregates with compact and irregular structures. Conversely, LLPS proceeds at the increase of salt content, through the formation of liquid droplets of coacervates with an ill-defined fractal organization. ITC data indicate that both LSPS and LLPS phenomena are rather enthalpically driven. A high binding constant with a stoichiometry of ~100 LYS per ALG are obtained under conditions favoring aggregates or coexistence of aggregates/coacervates. A 127-fold decrease of the binding constant was obtained when adding further salt, i.e. when only coacervation occurs, highlighting the complex charge neutralization process occurring in that case. To suimmarize, the results of the present study highlight the critical role of ionic strength in modulating the protein-polysaccharide interactions, offering valuable insights for optimizing biopolymer assemblies in various industrial and biomedical applications.

Coacervation and aggregation in lysozyme/alginate mixtures

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Keywords (5 max): Aggregation, Complex coacervation, Ionic strength, Phase diagram, Droplets-based millifluidic

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Abstract: Upon electrostatic interactions, the mixture of oppositely charged macromolecules separates into a macromolecule-rich phase coexisting with a diluted phase. The phase separation is either a liquid-liquid phase separation (LLPS) forming complex coacervates, or a liquid-solid phase separation (LSPS) forming aggregates. Here, we investigate the assembly of the positively charged protein lysozyme (LYS) with the negatively charged polysaccharide alginate (ALG) at pH 7 under different conditions of mixing ratios, total concentration, and ionic strength using a droplets-based millifluidic device. A 3D phase diagram, with the concentrations of salt, lysozyme, and alginate as the 3D coordinates, gives a thorough description of the monophasic, liquid-solid, and liquid-liquid phase separation areas and the regions where both solid and liquid phases coexist. The thermodynamic aspects behind these two kinds of complex formation are investigated using isothermal titration calorimetry (ITC). Aggregation is associated with a strong affinity between LYS and ALG, with a 100 LYS : 1 ALG stoichiometry ratio, whereas coacervation at higher salt concentration is associated to a strong decrease of the binding affinity between the two biopolymers.

Species-specific microstructure quantification of rennet-based milk gels

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Keywords: Cow, Sheep, Goat, protein aggregation

Abstract:

The dynamics of protein aggregation in rennet-based milk gels significantly influence the gelation process, syneresis behavior, gel network, and final product characteristics. Such aggregation is determined by the physicochemical properties of the milk, that across cow, sheep, and goat vary considerably. The different composition of milk from these different sources, particularly protein and fat content, total solids, and the ratio of the four major caseins (αs1, αs2, β, κ), directly influences the casein aggregation dynamics induced by rennet addition. These compositional variations, thus, significantly impact the formation and structure of the resulting gel network.

By employing advanced characterization techniques such as Stimulated Emission Depletion (STED) and Spinning Disk Confocal microscopy, and rheology, we revealed nanoscale microstructural features of rennet-based gels of cow, goat, and sheep milk, and correlate it with their macroscopic characteristics and flow behavior through novel computational quantification techniques. This approach provides valuable insights into the relationship between milk composition, gel formation dynamics, and final product, while demonstrating the efficacy of our developed computational analysis tools. The obtained quantification parameters are valuable predictors of the final product structure and stability, which are also useful for the characterization of other colloidal systems.

Gelation of Soluble and Insoluble Pea Protein Fractions induced by Microbial Transglutaminase

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Keywords: pea protein, commercial isolates, gelation, microbial transglutaminase, solubility

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Abstract: (250 Words Max)

Plant proteins are increasingly used as the basis for food matrices, yet archiving solid gel structures remains challenging. Commercial plant protein isolates contain varying amounts of soluble and insoluble proteins, which can affect gelation properties. This study investigates the gelation properties of soluble and insoluble pea protein fractions, with a focus on their cross-linking potential using the enzyme microbial transglutaminase (mTGase).

After screening twelve commercial pea protein isolates, we selected powders with the highest and lowest solubility to represent market variability. The soluble and insoluble fractions were separated by aqueous extraction at pH 9 and subsequently freeze-dried. After characterization, high-protein oil-in-water (o/w) emulsions were prepared and analyzed using rheometry with and without mTGase. The viscoelastic properties were determined in time, frequency, and amplitude sweeps. Storage modulus (G'), loss modulus (G''), loss factor (tan δ), slope of G'(ω), and the linear viscoelastic (LVE) region were evaluated.

The results showed that the protein and ash content of the fractions varied depending on the solubility of the isolate used. All fractions exhibited gel-like behavior during time and frequency sweeps, as indicated by G' > G''. Gel strength increased in the presence of mTGase, as evidenced by a lower tan δ, a slightly lower slope of G'(ω), and an extended LVE region, particularly in the soluble fractions.

These results highlight solubility as a key factor in mTGase-induced gelation and suggest that the soluble fraction is a preferred substrate for mTGase cross-linking and a more suitable basis for food matrices requiring solid gel structures, such as vegan cheese.

From Structure to Failure: Fracture Behaviour in Meat and Plant-Based Meat Analogues

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Keywords (5 max): Texture properties, Fibrous structure, Plant-based meat analogues, Spun meat analogues, Dynamic mechanical analysis in compression

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Abstract: (250 Words Max)

While plant-based meat analogues become a popular sustainable alternative to meat, they often fail to replicate the sensory and textural complexity of real meat. A critical challenge lies in mimicking meat's anisotropic properties that are essential for its characteristic bite and chew. This study investigates anisotropy and fracture behaviour in meat and three meat analogues, including two commercially available products. The meat analogues were created via extrusion (top-down approach), extrusion 3D printing (top-down approach), and with an innovative spun fibre technology (bottom-up approach).

Structural and mechanical properties were characterized using multiple techniques. Scanning electron microscopy was used to examine the microstructure, tensile tests determined the young's modulus. Texture profile analysis was used to characterize hardness and springiness, and dynamic mechanical analysis in compression was used to assess the complex extensional modulus and loss factor tan δ.

Key findings indicate that meat exhibits low anisotropy in springiness, and complex extensional modulus but high anisotropy in hardness. Extruded and 3D-printed analogues displayed inverse anisotropy trends, while the spun analogue closely resembled the anisotropy of meat. Stress-dependent behaviour further differentiated the samples: meat showed an exponential increase in loss factor tan δ (stress-induced softening), while meat analogues displayed a linear increase (uniform network). Fracture behaviour varied by processing, with spined analogues exhibiting a mix of fibre and interfiber breakage, resembling meat's fibre-dominated fractures.

This analysis highlights the impact of processing on anisotropy and fracture behaviour, advancing the development of meat analogues that better replicate real meat texture and therefore improve the sensory experience.

Hydrodynamic Theory of Coupled Binary-Fluid Surfactant System

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Keywords (5 max): Emulsions, surfactants, and interfaces.

Abstract (250 Words Max): We derive the hydrodynamic equations of coupled binary fluid and surfactant systems from microscopic forces and torques. At the microscopic level, the surfactant molecules are modelled as dumbbells, which can exert forces and torques on the fluid and the interface. By explicitly considering the molecular alignment, we then derive coarse-grained hydrodynamic variables, such as fluid density, fluid velocity, surfactant concentration, and surfactant polarization. The latter represents the average orientation of surfactants, which is crucial in preventing surfactant-laden droplets from coalescing with each other. Finally, we also derive the effective interfacial tension as a function of surfactant concentration.

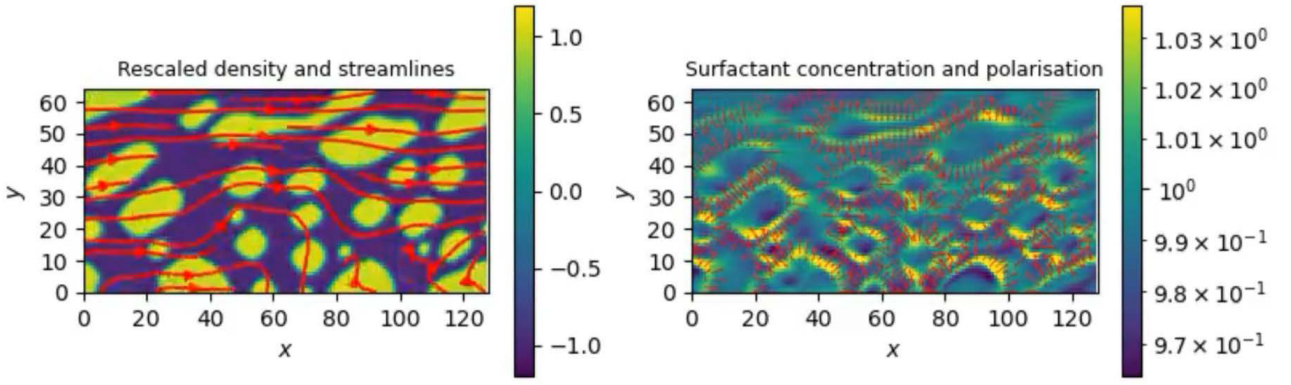

Figure 1: Left panel shows the relative density of the binary fluid. Yellow represents fluid phase A (e.g. oil) and blue represents fluid phase B (e.g. water). Right panel shows the surfactant concentration (yellow) and polarization (red arrows). We may observe the surfactant molecules are concentrated mostly at the interfaces.

Whey protein aggregates modify the structuration of curd during the enzymatic coagulation of milk

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Keywords (5 max):

colloid, filler particle, gelation, rennet, casein micelle

Abstract : (250 Words Max)

The enzymatic gelation of milk takes place following four key-steps (hydrolysis; flocs aggregation; strand formation; aging and syneresis). Milk is often preheated, inducing the aggregation of whey protein (WP) in order to increase the yield of dairy products. While the literature on the formation and structure of WP aggregates is abundant, their role in the casein micelles aggregation and underlying mechanisms is not fully elucidated, especially when independently formed WP aggregates are added in milk.

Our objective was to study the effect of WP aggregates on the milk gelation by SAOS (Small-Angle Oscillatory Shear), CSLM (Confocal Scanning Laser Microscopy), and particle aggregation quenching.

At the same storage modulus, milk gels with increasing concentration of WP aggregates displayed the same rheological signatures in frequency and oscillation stress sweep, though the time needed to reach the same storage modulus value was longer. These gels featured smaller serum pores and kept a higher water content after syneresis. Not only the gelation was slowed down, but its mechanisms was also changed, especially during the primary aggregation of casein micelles, strands aging, and serum pore formation.

Structural Dynamics of Amaranth Gels

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Keywords (5 max): Pseudocereal, Protein-starch complexes, Protein extraction, Rheological properties

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Abstract: Amaranth is a protein-rich pseudocereal with a high starch content and a possible raw material in the development of edible soft foods such as gels. The protein-starch complexes are polyfunctional and useful in food systems. The goal of this study was to examine the ability of amaranth-based complexes to create gel systems using a rigorous experimental technique and comprehensive analysis. Proteins and starch were extracted from amaranth and assembled into complexes under optimized conditions. Proteins were purified by alkaline solubilization and isoelectric precipitation, whereas starch was refined through alkaline steeping and sedimentation. The effects of complex concentration (5-15% w/v) on gel strength, thermal stability, and rheological properties were studied. The gels were examined using scanning electron microscopy, Fourier-Transform Infrared Spectroscopy (FTIR), Differential Scanning Calorimetry, and dynamic rheology. Turbidity increased as protein was introduced. Techno-functional analysis indicated that protein increased the water absorption index of all the samples, indicating increased hydration capacity. Syneresis analysis indicated that while unmodified starch indicated significant loss of water over time, addition of protein reduced syneresis. Pasting characteristics determined that the addition of protein improves swelling resistance, indicating a competitive water-binding mechanism. Rheological characterization demonstrated that increasing protein amount modified the viscoelastic behavior of the samples, improving storage modulus and loss modulus, indicating increased gel stability. Texture profile analysis determined that incorporation of protein produced more organized gel networks. Microstructural analysis identified a homogeneous network of biopolymers, while FTIR spectra indicated hydrogen bonding.

Do Pickering particles provide protection against metal-catalyzed lipid oxidation in emulsions?

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Abstract

Many studies have explored the ability of Pickering particles to physically stabilize oil-in-water emulsions through a protective barrier effect at the interface. It has been proposed that this physical barrier could also contribute to preventing lipid oxidation. However, it is questionable whether the porous structure of the particle layer can effectively prevent small prooxidants, such as iron ions, from readily contacting the lipid substrate. In this study, silica particles were used as a model system to investigate the ability of adsorbed particle layers to reduce lipid oxidation in emulsions according to their electrostatic charge. This was achieved by systematically varying the pH and ionic strength of the continuous phase.

Oil-in-water emulsions were prepared and incubated with and without an iron catalyst, and their lipid oxidation stability was monitored over a week. Lipid oxidation was monitored by the consumption of oxygen in the headspace and the formation of lipid oxidation products (hydroperoxides and aldehydes). Lipid oxidation progressed more rapidly at pH 7 compared to pH 3 in emulsions without added iron, likely due to the attraction of trace iron ions by the negatively charged particle layers. The addition of NaCl (100 mM) exhibited a pro-oxidant effect at pH 7, which may be attributed to a slight increase in iron solubility. The addition of an iron catalyst strongly accelerated oxidation, particularly at pH 3, likely because of the higher solubility of iron in acidic conditions. The present study demonstrates the potential to control lipid oxidation rates by modulating the solubility, location, and binding behavior of iron in particle-stabilized emulsions.

Keywords: Pickering emulsions, silica, lipid oxidation, iron.

Raman spectroscopy of fat-rich foods

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Keywords : Fat-rich foods, Raman spectroscopy, multiscale analysis

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Abstract :

Raman spectroscopy is a powerful and non-destructive analytical technique that provides valuable information about molecular composition and structure. It is most often used for component identification via molecular fingerprinting. Nowadays, Raman spectroscopy is used in a wide variety of domains, to complement X-ray scattering studies, confocal laser scanning microscopy and Fourier transform infrared spectroscopy.

In the domain of food science, Raman spectroscopy is specifically valuable as it offers 1) molecular characterization and structure identification, 2) microscale component localization and 3) in situ measurements, while preserving a sample's microstructure.

This presentation aims at sharing recent insights from Raman spectroscopy analysis applied to fat-rich food systems. The data set includes time-resolved and temperature-controlled data, aiming at polymorphic identification, spatial location of the triacylglycerol molecules and microstructure mapping. The complexity of the studied matrices gradually increased from pure triacylglycerols, over trigacylglycerol mixtures, plain fats, wax-based oleogels, emulsions and suspensions. In each of these complex matrices, the different components were localized, illustrating the added value of Raman spectroscopy to light microscopy and confocal laser scanning microscopy. The application of different laser wavelengths and different processing methodologies, including Euclidean distance mapping and k-means clustering, enhanced the versatility of the study .

Under pressure – understanding the physics behind brewing espresso

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Keywords: coffee, extraction, pressure, porous media, dissolution

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Abstract : Coffee brewing in an espresso machine requires the flow of hot water under high pressure (ca. 6-9 bar) through a compacted layer of ground coffee. During percolation, the coffee bed is extracted and dissolved (up to 20% of mass), as can be shown by observing the TDS (total dissolved solids) percentage of the liquid coming out of the espresso machine. Ideally, extraction is uniform, but flow instabilities sometimes lead to channelling, where water preferentially passes through localized paths, reducing extraction efficiency and altering the final brew quality.

In controlled laboratory conditions, we measured TDS and the mass of the liquid coming out of the espresso machine as a function of time to model how the flow of coffee depends on the water pressure. While at low extraction pressures (below 6 bar) ground coffee obeys Darcy's law, at pressures used in real espresso brewing (between 6 and 10 bar), the flow rate is weakly dependent, or even decreases, with applied pressure. Therefore, a revised constitutive model should be established. The results of our measurements serve as a basis for numerical and theoretical modelling of porous bed extraction.

Additionally, we use computer tomography to visualize coffee bed deformation and the phenomenon of channelling, aiming to construct a 3D atlas of porous bed dynamics.

Deposit characterization for photoprotection performances

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Keywords (5 max): multi-scale characterizations, emulsions, cosmetic

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Abstract : Sun protection has become essential due to the increasing awareness of the harmful effects of ultraviolet radiation (UVR). While sun avoidance and protective clothing are primary defenses, sunscreens play a crucial role in minimizing UVR exposure. Therefore, optimizing sunscreen performance requires a holistic approach considering filter selection, formulation design, and encouraging proper usage habits. Film irregularities caused by the skin's complex surface topography and application methods can lead to uneven distribution and reduced SPF. In the literature it has been shown that the homogeneity of the sunscreen after application is a key parameter to be able to develop higher performances. The optimum theoretical deposit is a perfectly homogeneous deposit in term of thicknesses and filtering systems repartition. Also, there is a lack of fine characterization at different scales of the thickness repartition on different substrates, both in vitro and in vivo. In this work, we want to develop new methods to characterize the deposit homogeneity and link the modification of thickness with the performances measured. To this end, we changed the composition in a set of sunscreen formula without modifying the filtering system and we show that a shift of performances is observed. Finally, these methods will allow us to go forward in a better knowledge of the organization of sunscreens on complex substrates which will help to design better and more protecting products.

Enzymatic Hydrolysis Alters the Structure and Surface properties of Acacia *senegal* Gum

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Speaker: Hao Li; e-mail: hao.li@inrae.fr

Keywords (5 max): Acacia gum, protease, hydrolysis, structure, surface adsorption

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Abstract : Acacia gum is a naturally occurring, heterogeneous mixture of arabinogalactan-proteins, valued for its surface properties in industrial applications. However, the impact of enzymatic treatments on its structural and functional characteristics remains poorly understood. In this study, we investigated the effect of four proteases (papain, subtilisin A, proteinase K, pronase) and three glycosidases (β-galactosidase, β-glucuronidase, α-rhamnosidase) on the structure and surface properties of Acacia *senegal (*A*. senegal)* gum. The proteolysis effects on A. *senegal* gum were dependent on the molecular weight (M_w) and protein content of its macromolecular fractions separated by hydrophobic interaction chromatography. The high-M_w arabinogalactan-protein (AGP) fraction, HIC-F2, which constitutes ~10% of the total gum with an average M_w of ~1.6×10^6 g·mol^{-1}, was significantly hydrolyzed by all tested proteases, albeit to varying extents. By contrast, the arabinogalactan-peptide (AG-peptide) fraction, HIC-F1, which represents the predominant fraction (~90%) with a M_w of ~3×10^5 g·mol^{-1}, exhibited negligible proteolysis. Notably, HIC-F2 hydrolyzed by mixed proteases yielded species with a M_w comparable to HIC-F1. Structural analysis revealed three distinct correlation lengths in both HIC-F2 and HIC-F1, which remained unchanged following proteolysis, likely reflecting multiple length scales of the carbohydrate units. Also, HIC-F2 population was primarily responsible for the surface adsorption of A. *senegal* gum, whereas HIC-F1 demonstrated minimal interfacial activity. Regardless of their specificity, all proteases significantly reduced the surface load and interfacial viscoelasticity of A. *senegal* gum, with a strong correlation between the M_w of hydrolyzed AGPs and their adsorption capacity. Conversely, the tested glycosidases did not induce detectable structural modifications in A. *senegal* gum nor influence its surface load.

Pickering Emulsions in Salad Dressings: A Physicochemical Perspective

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Presenter: Thang Tran

Keywords (5 max): Protein based Janus particles; Pickering emulsions, Lipid oxidation, Omega-3 PUFA fortification, Salad dressing

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Abstract : (250 Words Max)

Our study explores the potential of Pickering emulsions (PE) stabilized with Janus particles (JP) to enhance the physicochemical properties of PUFA-rich 2.5 wt% fish oil-in-water emulsions and examines their effects when used in fortified salad dressings. These JP were fabricated by electrohydrodynamic co-jetting technique with caseinate (1.0 wt%) and zein (4.0 wt%) and their bicompartmental structure was evaluated with CLSM and SEM. PE produced with JP were evaluated for physical stability with dynamic light scattering, creaming index. Lipid oxidation of these emulsions was measured by monitoring the formation of peroxide compounds and volatile compounds together with the depletion of tocopherols for 10 days. Emulsions stabilized with JP showed good physical stability with stable droplet size distribution with droplet size, [D4,3] around 1 μm compared to sodium caseinate-stabilized emulsions for which D[4,3] increased from 0.3 to 0.8 μm during 10 days storage. While peroxide formation and tocopherol depletion were similar in both, volatile compounds formed much slower in PE with JP, suggesting their role in inhibiting lipid hydroperoxide breakdown. Salad dressing was formulated with fish oil (2.5 wt%) in various forms: PE, conventional emulsions, and neat fish oil. These dressings were stored and assessed for physicochemical properties, odor, and appearance for 4 weeks. Evaluation of lipid oxidation was performed the same way as for emulsions while odor and appearance were assessed by a sensory panel every 2 weeks. This study provides insights into the physicochemical properties of PE as well as the sensory appeal of salad dressing fortified with these PE.

Particle-assisted stabilisation of emulsions using cellulose microfibrils and potato protein

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Keywords: Cellulose microbfibrils, protein, emulsions, rheology, Confocal laser scanning microscopy

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Abstract:

In this study, we investigate the formation of emulsions stabilised using both cellulose microfibrils and potato protein together. The microstructure of the emulsions is characterised via confocal laser scanning microscopy and cryo-SEM, to elucidate the mechanism by which the emulsions are stabilised. The microstructure data is then linked to the flow behaviour of the emulsions, measured via oscillatory rheology. We find that the mode of emulsions stabilisation is dependent on the concentration of the both the cellulose microfibrils and protein, as both can adsorb to the interface of the emulsion droplets. Finally, we demonstrate that these materials can be used to synergistically stabilise the emulsions, however this is pH dependent.

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pulse globulins and albumins on the air-water interface

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Keywords (5 max): Pulse protein, Air-water interface, Interfacial dilatational rheology, Interfacial structure, Correlation analysis

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Abstract : Pulse protein isolates are promising substitutes for animal protein in foam preparation, but they typically are complex mixtures of multiple proteins, and the contribution of the individual proteins to the behavior of the mixture in air-water interface stabilization is largely unknown. The major protein fractions in isolates are the globulins and albumins, and this study systematically investigated the molecular properties, and interfacial and foaming properties of these two fractions for three different pulses: lentils, faba beans and chickpeas. While each fraction is different, we find that foamability and foam stability can be strongly related to the denaturation enthalpy of the protein fraction, emphasizing the role of protein conformational flexibility in the behaviour of protein-interface systems.

Monitoring the interfacial crystallization of high melting point oil by drop tensiometry

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Keywords (5 max): Interfacial crystallization, High melting point lipids, Interfacial rheology, Coconut oil, Drop tensiometer.

Abstract: In many lipid-containing foods, the structure, stability and quality attributes are driven by the crystallization behavior of triacylglycerols (TAGs). Lipid crystallization is largely modulated by the dispersion state of the lipids, and notably the occurrence and composition of fluid interfaces between immiscible phases. This study examines the interfacial behavior of coconut oil (melting point around 25 °C) at different temperatures using the pendant or rising drop method. Investigations were conducted at both the oil-air and oil-water interfaces by measuring surface tension, viscoelastic modulus and standard error from 30 to 20 °C. Experiments were performed on commercial and purified oils to assess the impact of surface-active impurities in the oil phase (e.g., free fatty acids, polar lipids) upon thermal transitions. These observations were complemented by analyses of bulk behavior, following transition peaks using differential scanning calorimetry (DSC).

Among the key findings, the study reveals changes in the surface tension and the viscoelastic properties of the oil-air interface with decreasing temperature. When the coconut oil drop was kept above the crystallization temperature, surface tension decreased gradually whereas a sudden drop in surface tension was observed when the temperature decreased. Oscillatory experiments showed a growth of the elastic modulus over time, suggesting the formation of a highly elastic network confirmed by visual observations. We also demonstrate that since drop tensiometry assumes that the drop profile is Laplacian and that equilibrium is reached, recording the standard error of the measurement thus becomes a sensitive indicator of an interfacial membrane formation.

Formulation of emulsion and foam production in view of making solid food foam

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Preference: TALK & preferred session : T2 - Dispersed systems: emulsions, foams, interfaces

Keywords (5 max):
Food foam, emulsion, proteins, microfluidics

Abstract (250 Words Max): Foams as soft materials has been studied for various applications going from cosmetic to foods. In the food industry, the formulation and the manufacturing process are known to impact deeply the properties of such products. Therefore, tuning to less energy consuming processes and using clean label compounds need to develop new strategies. A recently started project, ANR PROFHEAT, aims to focus on these aspects, with the objective of developing a complete continuous process based on intensified devices for the foam production and on alternative heating processes for the foam solidification. In this work, the formulation of foamed emulsions is studied to meet required mechanical properties of a solid food foam.

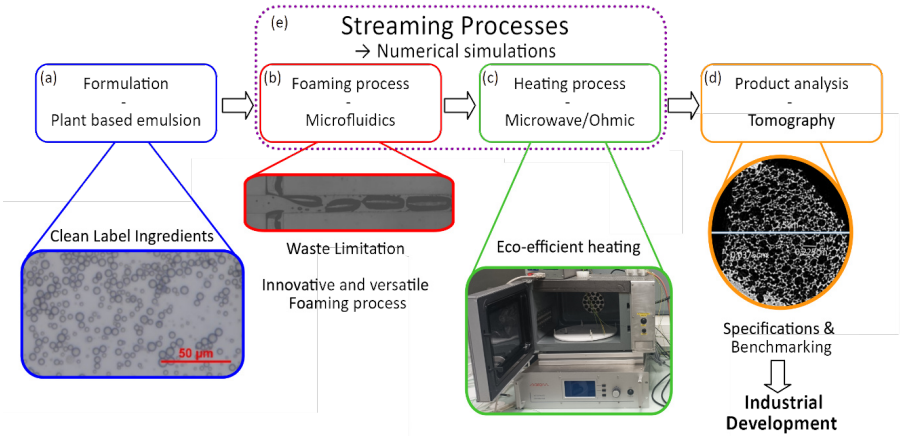

Figure 1: Overview of the project. From formulation (a) to transformation process (b,c,e) and a characterization(d)

The formulation consists in a plant-based emulsion made with oil, proteins and texturing agents. Proteins are a key ingredient as surfactants, as well as a solidifying agent through their denaturation at around 60-80°C. The rheology of texturing agents is also a critical point, as a high throughput microfluidic device is intended to be used to produce the foam in this project.

Microfluidic devices have been shown to be able to deliver fine foams with good mechanical characteristics, however these systems have only yet been invested with simple model solutions. This contribution focuses on the development of a formulation regarding the limiting points cited. Therefore, different kinds and mass fractions of ingredients and flow conditions are tested in order to fulfill the implementation of microsystems and get stable foams.

Molecular predictors of macroscopic foam functionality of soy proteins

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Keywords (5 max):functionality prediction, molecular predictors, foaming properties, plant proteins

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Abstract : The poor applicability of plant proteins in food products is primarily due to unknowns in their techno-functionalities, such as foaming, emulsifying, and gelling properties. While experimental testing of plant proteins can help overcome these unknowns, it is labour-intensive and time-consuming, requiring extensive measurements and analyses. This project aims at finding molecular predictors that could facilitate the predictability of the foaming properties of soy proteins. Such molecular predictors could be hydrophobicity, solubility, degree of denaturation, and aggregate size, which can directly predict the macroscopic properties of proteins. To overcome the workload in understanding the protein functionality, the project aims to identify the minimal information necessary to predict the macroscopic functionality.

To achieve this, we study soy proteins extracted using various methods, which yield proteins with different compositions, purities, and functional properties[1]. The molecular and foaming properties of these proteins are then analysed, and we apply statistical approaches to identify correlations between molecular parameters and foaming properties. This project aims to determine the essential molecular predictors for accelerating decision-making in product development, ultimately enabling more efficient and effective use of plant proteins in novel food formulations.

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[1] Yang, J., Mocking-Bode, H. C. M., van den Hoek, I. A. F., Theunissen, M., Voudouris, P., Meinders, M. B. J., & Sagis, L. M. C. (2022). The impact of heating and freeze or spray drying on the interface and foam stabilising properties of pea protein extracts: Explained by aggregation and protein composition. Food Hydrocolloids, 133, 107913. https://doi.org/10.1016/j.foodhyd.2022.107913

The effect of pH and Temperature on Potato- and Faba Protein-stabilized Emulsions: Combined Bulk and Interface Properties determine Stability

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Keywords : Plant protein, bulk rheology, oil-in-water (O/W) interface, emulsions stability

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Abstract :

Many alternative proteins have been tested for their applicability in food emulsions at room temperature. An aspect that is much less addressed is how emulsion stability evolves upon heat treatment at different pH. This study systematically investigates the effects of pH (4–7) and temperature (20–95°C) on the bulk and interfacial properties of emulsions stabilized by two potato protein isolates (patatin-rich POPI-200 and protease inhibitor-rich POPI-300) and faba protein isolate (FPI). We connect these findings to the physical stability of 45 wt% O/W emulsions.

The gelation temperatures of POPI-200 and POPI-300 were 59°C and 77°C, respectively. FPI exhibited no thermal gelation but formed a weak gel at room temperature near pH 4. The storage modulus of POPI solutions increases near their isoelectric points (IEP), though high NaCl concentrations reduced this effect, resulting in similar moduli for both POPIs at pH 4 and 7 during heating and cooling. At the O/W interface, POPIs formed more elastic layers than FPI, with higher elastic moduli at pH 4 than 7 at higher temperatures. Salt addition reduced interfacial elasticity for all proteins, but elasticity was higher near the IEP even with NaCl present. Emulsions stabilized by the POPIs showed higher physical stability (smaller droplet size and less oiling off) compared to FPI, likely due to higher bulk viscosity and enhanced interfacial elasticity.

These findings highlight the relevance of potato proteins, particularly POPI-200, for creating thermally stable food emulsions under different pH and salt conditions, offering valuable insights for plant-based formulation development.

Influence of the Use of Breaker Plates on the Formation of Fibrous Structures in High Moisture Meat Analogues

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Keywords (5 max): meat analogue, breaker plate, extrusion

Abstract :

A significant driver of climate change is the food industry, with meat production being the largest factor. It is therefore the task of the food industry to facilitate the transition to an alternative plant-based diet for large segments of the population. Although there is already a wide range of vegan meat substitutes available, optimization is needed in approximating the complex fiber structures that determine the mouthfeel of meat.

The high-moisture extrusion process currently stands as the industry´s foremost method for generating well-defined fibrous structures from plant proteins. In this process, thermomechanically modified protein is shaped and solidified within the screw section, ultimately forming in the cooling die. The structuring mechanisms postulated in earlier publications operate on various length scales up to 500 micrometers. Industry´s interest in patents reflect the significance of cooling die geometric specifications on structure formation. The influence of breaker plates within the die section of the extruder on the formation of anisotropic structures has so far been scarcely investigated.

In the presented work the impact of the geometry of breaker plates on operational parameters and product properties is elucidated. The parameters of plate thickness, hole diameter and the ratio of the flow area of the breaker plates to that of the cooling die are varied systematically. It was found that with the use of breaker plates another controllable length scale of structure can be added to these of hitherto postulated structuring mechanisms.

Sex-Based Differences in In Vitro Digestibility of Milk and Oat Drink, and Powder Counterparts

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Keywords sex-specific differences, in vitro digestion, proteomic analysis, bioactive peptides, bioaccessibility.

Abstract:

This study investigates sex-based differences in the digestibility of bovine milk and oat -based milk alternative, utilizing an *in vitro* digestion model to assess the impact of sex on protein breakdown. Protein is a crucial macronutrient of great importance from the sustainability and health perspectives, yet the digestibility of animal and plant-based proteins are only now gaining extensive research, with consumer sex remaining as an underexplored variable. This research used a semi-dynamic *in vitro* digestion model to examine how males and females metabolize two protein sources and their concomitant protein powder products. Results indicate that physiological differences between males and females delineate differences in gastric and intestinal protein clotting and breakdown into peptides and amino acids. Interestingly, females exhibit a different proteolytic trajectory leading to higher efficiency in breakdown of oat proteins, while males show a tendency for improved breakdown of bovine milk proteins. LC-MS proteomic analyses also stress that males and females were able to generate different bioaccessible peptides. In the case of milk, male gut conditions liberated various known bioactive peptides with antimicrobial, DPP-IV inhibitor and cholesterol regulating activities. Contrary, female gastric conditions led to the liberation of an osteoanabolic peptide. Moreover, female gut conditions were able to liberate more free amino acids from oats rather than from milk while male conditions yielded an inverse trend. Thus, the findings suggest consumer biological sex could

have significant ramifications to the rational design of future foods and food reformulation efforts.

LUBRICATIVE PROPERTIES OF SEMI-CRYSTALLINE LIPID SYSTEMS

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Keywords (5 max): Fat Crystal Network; Palm Oil; Crystallization; Rheology; Tribology.

Abstract : The crystal network of fat-continuous food products determines its functionality, which includes the mouthfeel experienced upon consumption, originating from tactile sensations detected by oral receptors. Soft tribology is an emerging analytical technique used to assess the lubricating capacity of foods by measuring frictional forces between two surfaces, mimicking the tongue-palate interaction in the oral cavity. However, to this day, tribological research on fat-continuous systems remains scarce.

In this study, the lubricative properties of semi-crystalline lipid systems were explored using a novel tribological fitting approach. Hereto, three blends of palm and canola oil were subjected to slow, medium and fast crystallization to induce microstructural differences, confirmed through polarized light microscopy. Solid fat content measurements pointed out that a high-melting crystalline fraction persisted at 35°C in the samples, a temperature relevant for oral processing. Subsequent light and electron microscopy revealed that this fraction corresponded with crystalline particles of diverse sizes and shapes. Image analysis was used to quantify these structures, revealing diameters ranging from 10 to 100 µm, influenced by the crystallization conditions of the sample. Tribological analysis highlighted the importance of this dispersed crystalline phase on the lubrication properties across different lubrication (sub)regimes of the extended Stribeck curve. Key parameters, such as the area and coefficients extracted from tribological fitting, showed correlations with particle dimensions, SFC and rheological parameters.

This work demonstrates a novel approach of tribological data interpretation, applied on fat-continuous systems, demonstrating the importance of crystalline fat in lubrication behavior of samples.

Water dispersible edible films based on cellulose microfibrils

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Keywords (5 max): Cellulose Microfibrils, Edible films

Abstract : Edible films are constructed of cellulose microfibrils (CMFs) and xanthan gum (XG). To control the aggregation of CMFs when dried, water soluble polysaccharides are added. Water insoluble dietary fibre comprising cellulose, hemicellulose and pectin was used as a source of CMFs. The dispersions with different ratios between of XG and CMF are obtained by homogenisation. The dispersions were made into films by solvent casting and evaporation under vacuum. The resulting films' thickness ranged from 22 to 32 micrometre and had a density ranging from 1.1 to 1.6 g/mL. The film thickness increased with increasing CMF/XG ratio, while the density inversely scaled with this ratio. Uni-axial mechanical testing was performed to obtain tensile strength (TS), elongation at break (EAB) and Young's modulus (E). Films with higher CMF/XG ratios had higher TS and E, but lower EAB than films with a low CMF/XG ratio. Glycerol was found to be an effective plasticizer, reducing TS and E, but increasing the EAB of all films. Dispersibility of the films was obtained by measuring the viscosity in water. Films became less dispersible when the CMF/XG ratio increased and at low CMF/XG ratios the rheology of the dispersions was fully recoverable to the one of the initial dispersions. Our result show that these films could be used as a delivery system for beneficial ingredients in food products.

On the Effect of Insoluble Hydrophobic Heterogeneities on the Wetting Dynamics of Soluble Thin Films.

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Keywords (5 max): Wetting, Heterogeneities, Dynamics, Solubility, Evaporation

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Abstract (250 Words Max):

Recent studies have highlighted the complex mechanisms governing the spreading of a solvent onto a homogeneous soluble film, such as water on soluble polysaccharides. The presence of surface fat slows down the wetting of spray dried food powders, but this phenomenon is not yet understood quantitatively.

In this study, surface heterogeneities were created by the ink-jet printing of cocoa butter onto water-soluble maltodextrin thin films to produce hydrophobic deposits with a range of area coverages. The spreading dynamics of water was studied controlling relative humidity. Area coverages above 1.2% were found to decrease the contact line speed and increase the contact angle. The contact line was deformed by the deposits of cocoa butter, causing in some cases periodic decelerations followed by accelerations. Area coverages above 26% led to a three-fold increase in the spreading time. These novel insights could help to design soluble heterogeneous surfaces meeting a desired wetting performance.

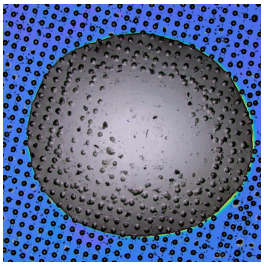

Figure 1: A droplet of water spreading on a soluble thin film decorated with hydrophobic fat patterns.

Mixed arabinoxylan and plant-protein gels

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Keywords (5 max): X-ray scattering, arabinoxylan, gels

Abstract :

To achieve the UN sustainability goals, and develop a healthy lifestyle, we need to increase the content of protein and dietary fibre polysaccharides from plant sources in food products. For this purpose, we have previously developed hydrogels by enzymatic crosslinking of arabinoxylans (AX) extracted from cereal by-products (e.g. wheat and corn bran) [1-2] with tuneable rheological properties and antioxidant behaviour [3]. We have now extended this approach by creating AX gels with plant proteins using the same enzymatic crosslinking process, and applying different heating treatments, resulting in polymeric networks with distinct supramolecular organisation. By varying the protein origin (pea, gluten and soy) and the AX:protein ratios, we obtain hydrogels with tailored rheological properties. We have further investigated the different formulations using X-ray scattering to understand the relationship between the structural features and the rheological properties of the hydrogels.

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[3] S Yilmaz-Turan, P Lopez-Sanchez, A Jiménez-Quero, T S Plivelic, F Vilaplana. Food Hydrocolloids 128, (2022), 107575

Title : High moisture extrusion to produce innovative plant proteins-based foods with algaes

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Topic : Development of gluten-free meat substitutes and exploring new plant proteins
Key words : High moisture extrusion, plant proteins, gluten free

The many constraints on meat production are leading more and more consumers to prefer plant-based protein products, which they are incorporating into their eating habits.The high moisture extrusion (HME) is a process that uses mainly vegetable proteins such as protein crops, cereals and pulses, and can be used to meet the challenge of imitating a 'meat-like' texture (Zhang et al., 2022). Algal biomass is considered to be a relevant protein alternative, offering ecological advantages as well as health and nutritional benefits. However, high moisture extrusion of macro-algaes has been little studied to date. To obtain a 'meat-like' texture via HME, the quantity and quality of the proteins and their synergies with the other compounds contained in the formulation need to be controlled, as do the thermodynamic parameters of the process. To do this, plant proteins, already standardised and controlled in the HME process (pea protein isolate...), were used as a control in order to add various quantities and qualities of algaes. The first results have shown a strong link between a product's ability to be extruded continuously and its ability to bind to water molecules. These results makes it possible to describe the mixing (powders and water) that takes place at the extruder inlet by knowing caracteristics of the raw material. The results analyses on extrudates show that the quality of the fibration is linked to the biochemical characteristics of the proteins used, mainly their solubility and their level of denaturation. Tests have also been carried out on sources of pulses (red lentil, fava bean) and oilseeds (sunflower, rapeseed) that have been little explored to date in HME. This initial work enabled us to identify the characteristics needed to control extrusion with legume proteins, before working on the incorporation of macroalgaes as a gluten substitute or additives such as methyl cellulose.

References :

Zhang, J., Chen, Q., Kaplan, D. L., & Wang, Q. (2022). High-moisture extruded protein fiber formation toward plant-based meat substitutes applications : Science, technology, and prospect. *Trends in Food Science & Technology*, *128*, 202-216. https://doi.org/10.1016/j.tifs.2022.08.008

Characterizing fibrousness in soft food materials

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Keywords (5 max): fibrousness, image analysis, multi-scale, heterogeneity, anisotropy

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Abstract (250 Words Max): Characterizing and quantifying fibrous structures across multiple length scales remains a significant challenge in food material science, particularly for determining texture-structure relationships that influence consumer acceptance. While fibrous structures, also defined as aligned networks, can be visualized over multiple length scales using multi-photon and super-resolution microscopy, robust quantification is still lacking. This study introduces and compares two in-house developed image analysis approaches for characterizing multi-scale fibrousness in soft food materials, with specific application to meat analogue products. The first method employs grey level co-occurance matrix (GLCM) analysis, combined with a line plot intensity analysis for quantifying fibre and fibre bundle thickness. The second method uses structure tensor analysis with variable integration parameters to study structural alignment differences across different length scales (Figure 1). Both methods were tested on a range of different meat analogues with different microstructures and could successfully discriminate between them and rank them according to fibrousness. GLCM analysis effectively identified the dominant orientation within the images and quantified the degree of overall alignment to this dominant direction. Here, isotropic structures resulted in low alignment scores and anisotropic structures resulted in high alignment scores. Structure tensor analysis revealed differences in fibre orientation across multiple length scales (1-60 pixels) allowing quantification of the degree of fibrousness at various hierarchical levels. Such microstructural analyses allow for further correlation to other material properties or sensory evaluation.

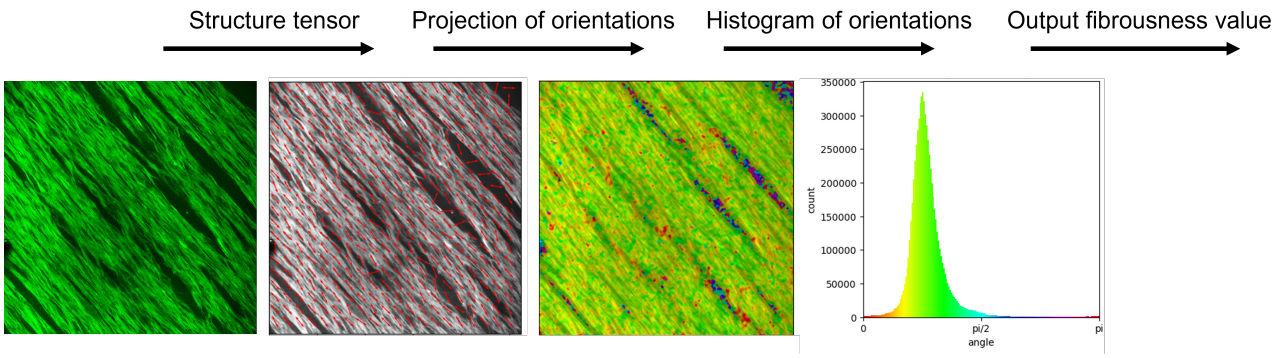

Figure 1: Fibrous microstructure imaged using multi-photon microscopy at 40x magnification and overview of the subsequent structure tensor workflow.

Synergetic Effect of Plant Proteins Mixtures for increasing foams formulations and properties

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Keywords: Interfacial rheology, Bulk rheology, Plant proteins mixtures, Foam quality.

Abstract:

Plant-based proteins have gained more attention in various industrial sectors including food due to their health benefits and environmental advantages. They become an option to replace classical Petro sourced surface-active agents for gellification, emulsification, and foaming applications.

Plant proteins from oilseeds that originated from France were used. The proteins were extracted from sunflower and linseed. Each protein isolate is able to produce and stabilize foams. Sunflower proteins isolate leads to a high foamability but low stability (6 hours). Linseed proteins isolates are able to produce weak foamability but the foams are stable for a long period (3 day).

The idea here is to mix the 2 plants proteins in order to enhance the foam properties. To this extent, mixture of two proteins with proportions of sunflower-linseed proteins of 50%-50%, 75%-25%, and 25%-75% were used.

The interfacial properties (surface tension and interfacial rheology) were studied in order to be correlated to the foam properties. The foam properties and the interfacial properties depend on the proportion of both proteins. All the mixtures produce better foam than each protein alone. The synergetic effect is highlighted for mixture containing 75% sunflower and 25% linseed proportion. In that case, a high foamability coupled to a very high foam stability are obtained. In particular, the foam remains stable during 7 days. This result is very impressive since most of proteins are only

able to stabilize foams for a couple of hours. This work paves the way for the development of bio-based materials stabilizers of foam products.

Plant-Based Proteins as Egg White Protein Alternatives in Meringue Model Systems

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Keywords (5 max): food foams, meringues, egg white protein, plant proteins, sucrose

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Abstract: Foams are essential in food, influencing texture, mouthfeel, and structural integrity, while providing important rheological properties. The foaming properties of eggs stem from their egg white component, which serves as a common foaming agent. However, conventional egg production, increasing due to growing global demand, has significant environmental impact. This has driven the need for replacements that completely replace or partially substitute eggs with plant-based alternatives. This study evaluated the properties of selected plant-derived proteins (wheat protein hydrolysate, potato protein, and aquafaba), in comparison to egg white proteins, not only in isolation, but within meringue batter systems. Individual and mixed systems were investigated to assess the potential for partial or full replacement. Meringue batters made with egg white protein exhibited lower densities and greater overrun than those made solely with plant protein alternatives. When egg white protein was partially replaced with aquafaba and potato protein, comparable foaming properties were observed, whereas lower functionality was noted for the wheat protein hydrolysate. These foaming studies revealed the role played by sugar in foaming stability across protein systems. Using potato protein and aquafaba, foam volume decreased faster with sucrose. This destabilization was linked to the formation of larger, more irregular air bubbles and increased coalescence, compromising foam stability in these systems. In contrast, sucrose enhanced foam stability in egg white protein and wheat protein hydrolysate solutions. These findings highlight the importance of studying protein functionality in relevant food matrices, and

provide insights into the structure–function relationships of complex protein systems for bakery applications.

Moringa protein-based Pickering emulsions: Formulation of Nutritious Food Spread

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Keywords Pickering emulsion, Plant-based emulsion, Moringa particle

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Abstract: There is a growing trend towards healthier food products of high nutritional quality with low contents of saturated fats, and as such low-fat food spreads have emerged as replacements for conventional margarines and butters. Several approaches have been employed to mimic the unique characteristics of fat, including the use of animal proteins for O/W emulsion spread and milk proteins for W/O low-fat spreads. However, current concerns on environmental sustainability, health and animal welfare make the case for the use of plant proteins as fat substitutes in formulated food.

Plant protein- based particles have proven to be advantageous as Pickering stabilizers as they are biodegradable, non-toxic, and provide a large possibility for surface modification. Research on the *Moringa Oleifera* (MO) protein has proven to have excellent anti-oxidant, anti-hypertensive and anti-diabetic properties and hence, along with MO oil, they can be used to develop W/O Pickering emulsions or bijels. It is difficult to separate the association mechanism of gelation and emulsification through protein aggregation which is another motivation for our studies.

We have undertaken a program to study Moringa based extracted particles by utilizing Optical Microscopy, Dynamic light scattering, and Small- Angle X-ray Scattering (SAXS) to examine structural stability and aggregations in aqueous suspensions at various pH. Raman and IR spectroscopy have been used to determine protein as well as sugar and lipid contents of the extracted particles, and rheometry was used to examine flow behaviors of these systems. Further work includes formulating food spread using starting from Pickering emulsions stabilized by these particles. Future work will also include smell and mouthfeel quantification.

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This work received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 956248.

Electric Field-Induced Assembly of Clay Particles at the Water-Oil Interface

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Keywords: Electric field, clay, water-oil interface, interfacial assembly, emulsions

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Abstract: Electric fields are widely utilized to manipulate the response of soft materials at fluid interfaces. Electric fields can significantly influence the distribution and movement of colloidal particles in multiphase systems such as water-oil emulsions. This study investigates the response of various types of clay at the water-oil interface under the influence of an externally applied electric field. The effects of clay type, interfacial properties of the fluids, electric field strength, and type were systematically evaluated. Experimental techniques such as interfacial rheology, optical microscopy, and zeta potential measurements are employed to analyze the particle response. We find that mineral composition plays a significant role for clay particles' alignment, aggregation, and mobility under an electric field. The research provides fundamental insights into the electric field-response of soft materials with potential applications in emulsion stabilization, and the design of tunable interfaces for advanced material systems, including food applications.

Rheology, microstructure and water holding of acid-induced gels from cross-linked caseinate

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Keywords (5 max): Rheology, microstructure, gelation, casein, cross-linking

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Abstract: Caseinate is a protein ingredient extracted by acid precipitation of casein from milk and used in many food applications due to its emulsifying, thickening and gelling properties. Enzymatic cross-linking of caseinate using transglutaminase can be employed to modify these techno-functional properties of caseinate and enhance its performance in food applications.

Previously, enzymatic cross-linking increased the stiffness of acid-induced caseinate gels, where the optimum cross-linking degree depended on the ionic composition. However, the microstructure of these gels has never been studied in detail.

This study investigated caseinate gels at a protein concentration of 27 g/kg regarding their rheological and microstructural properties, namely sodium caseinate, calcium caseinate, and caseinate in a 0.1 M sodium phosphate buffer.

The maximum G' observed in time-based small amplitude oscillatory shear experiments increased with cross-linking intensity for sodium caseinate but showed a maximum at moderate cross-linking for calcium caseinate and caseinate in 0.1 M sodium phosphate. The microstructure was more coarse for calcium caseinate gels compared to gels from sodium caseinate and caseinate in 0.1 M sodium phosphate, which aligns with the higher G' and water holding capacities determined. The effect of cross-linking on the microstructure was less distinct, although excessive cross-linking seemed to have resulted in greater pore sizes of the gel network. Image analysis for more quantitative evaluation of the microstructure is currently under progress.

The research facilitates a better understanding of the acid-induced structure formation of cross-linked caseinates, which is relevant in view of the rise of protein ingredients obtained from precision fermentation.

Dynamic proteins in freeze-structuring of food

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Keywords: freeze structuring, proteins, processing, suspensions, protein solubility

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Abstract: Plant-based food products are the rising stars of the food industry but often fail to deliver favorable nutritional and organoleptic properties. Freeze structuring (FS) has been proposed to deliver positive organoleptic properties by structuring suspensions through the formation of ice crystals. Although FS has been used in various food products such as Quorn and Kori Tofu, a deeper understanding of material and process parameters, particularly for proteins, is needed to optimize FS for food industry applications.

To address this shortcoming, we examined the microscale interactions during FS of protein systems, focusing on particle size and solubility of proteins. We investigated how size and solubility affect protein particle behavior and redistribution at the freezing front during freezing. We suggest that protein particle size and solubility are key material parameters in FS, demonstrating their effect on micro- and macrostructural organization. This, in turn, affects the structural outcome and the mechanical properties of the structured material. By understanding the structure-process-property relationships of proteins in FS, we aim to set a clear foundation for freeze structuring in food.

Interfacial and foaming properties of mung bean and pigeon pea proteins obtained from wet conventional extraction

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Keywords: Mung bean, Pigeon pea, Wet conventional extraction, Dilatational rheology, Air-water interfaces

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Abstract : Mung bean (MB) (*Vigna radiata*) and Pigeon pea (PP) (*Cajanus cajan*), both affordable crops rich in protein and dietary fiber, are important sources for developing plant-based products. In this study, the globulin-rich (GB) and albumin-rich (AB) fractions from MB and PP were separated using wet conventional extraction. We determined the adsorption kinetics and dilatational rheology to assess the interfacial behavior of these proteins at air-water interfaces. AB fractions from both plant sources adsorbed faster at the interface than the GB fractions. This could explain the twofold higher foam overrun of AB compared to their GB fractions. In amplitude sweeps, MB-AB showed the highest elastic dilatational modulus (E_d') at low deformation. This implied that MB-AB-formed interfacial film with higher stiffness compared to GB-fractions. The lower surface charge, smaller molecular weight and smaller particle size of AB may contribute to a denser surface coverage, resulting in strong in-plane protein interactions. Interestingly, PP-AB-stabilized interfaces exhibited a different behavior, despite its similar physicochemical properties to MB-AB. It possessed the lowest E_d' values and longest linear viscoelastic region, which indicate a low stiffness and highly stretchable interfacial film. The underlying factors contributing to these results are not yet been fully understood. This could be due to the presence of non-proteinaceous components (e.g., phospholipid, starch, and phenols) in the protein extract, or it might be the inherent molecular properties of the protein itself that governs its interfacial properties.

Harnessing Low-Acyl Gellan Gum Edible Coatings to Regulate The Starch Digestibility of Cooked White Rice.

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Keywords (5 max) : low-acyl gellan gum, protein-starch matrix, white rice, starch digestibility, predicted glycemic index

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Abstract :

The integration of hydrocolloid-based edible coatings in food design offers a novel strategy for modulating digestion kinetics and nutrient release. This study examines the effect of low-acyl gellan gum (LAGG) on the textural characteristics and starch digestibility of white rice cooked using conventional domestic methods. It was hypothesised that LAGG reduces starch digestion by the formation of a coating encapsulating the kernel, thereby modulating its structural properties and enzymatic accessibility. The evaluation was conducted using jasmine rice (high-glycemic index, high-GI), and parboiled rice (low-GI). Varying concentrations of LAGG (0–3%) were incorporated in cooking process to assess structural, textural, and digestive alterations of cooked rice. Microstructural analysis confirmed a hydrogel-like coating. FTIR and XRD characterization indicated increased β-sheet secondary protein structures and V-type starch–LAGG complexes. Texture analysis revealed increased hardness (8–26%) and reduced adhesiveness (18-31%). This relationship indicates that the addition of LAGG may not only improve the overall texture but also change the dynamics of oral processing, as evidenced by its impact on the enhancement of chewiness (1.4–2.3 times). In-vitro digestion assays demonstrated a controlled starch release, lowering predicted GI by 4–16%, depending on rice type and LAGG concentration. These findings highlight the potential of LAGG as a functional edible coating that modifies both mechanical and digestive properties of rice. This work advances the application of food hydrocolloids in tailoring texture and nutrient delivery for improved health outcomes.

3D food printing : from formulation to rheological behaviour

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Keywords (5 max): 3D printing, food gels, rheology, phase transition

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Abstract (250 Words Max): 3D printing is a major technological advance that has opened up new perspectives in various fields such as industry, medicine, art and design. However, 3D printing is not limited to the manufacture of objects; it also finds new applications in foods with potential such as personalized nutrition, reduced waste and innovative designs. When it comes to food 3D printing, a key consideration is the rheological properties of food inks.

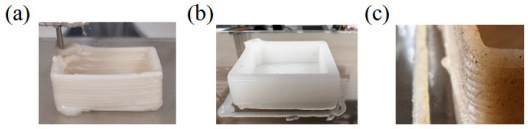

Figure 1: 3D printed objects : (a) Emulsion stabilized by potato proteins (b) Wheat starch suspension (c) Wheat starch suspension including brewer's spent grains

In this context, our study focuses on the development of new edible inks for 3D printing. Our printer works according to the principle of extrusion: the material, contained in a syringe, is heated and deposited on a mobile plate. We explore different plant based formulations such as protein-stabilized emulsions and starch suspension to promote the transition from animal products to plant substitute. By-products from the food industry (brewer's spent grains and others) are also included in the formulation for valorization purposes and as alternative nutrient sources.

Through rheological and thermal characterization of our ink, we evaluate their printability. As an example, the protein-based ink of potato, rich in protease inhibitor, has demonstrated excellent printing capacity in terms of flow and elasticity, as well as a phase transition with irreversible gelation at 60 ^{o}C. This phase transition insures the stability (in terms of mechanical properties) of the printed ink. A recently started project will explore new possibilities in terms of future products and consumer's acceptance using participative science methodology.

Protein Nanoparticles as Stabilizers for Pickering Emulsions: A small angle scattering study

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Keywords : Small angle scattering, SAXS, Beta-lactoglobulin, Pickering emulsions, High internal phase emulsions,

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Abstract : Pickering emulsions i.e. emulsions stabilized by solid particles instead of conventional surfactants, offer an eco-friendly and health-conscious alternative for emulsion systems [1]. In this study, we investigate β-lactoglobulin nanoparticles (BLGNPs), derived from whey protein, as food-grade stabilizers for Pickering emulsions. These nanoparticles are prepared via pH modification and ethanol-induced desolvation, yielding particles within the range (a few nanometers to over 100 nm) for stabilization [2].

Using synchrotron-based small-angle X-ray scattering (SAXS), as well as microscopy, rheology, and dynamic light scattering, we study the long-term structural development of these complex systems. We study BLGNP-stabilized Pickering emulsions and High Internal Phase Pickering Emulsions (HIPPEs), a subclass of Pickering emulsions where the dispersed phase occupies more than 74% of the total volume. We present findings on the effect of particle concentration (2–5 wt.%) and oil concentrations (10–70 wt.% for Pickering emulsions and 75 wt.% for HIPPE) in fresh, aged (≈ 90 days), and thermally aged conditions. SAXS analysis gives proof for aging-induced alterations, i.e., decreased scattering intensity and droplet coalescence [3], providing information on particle conformation and interfacial layer thickness.

This work highlights SAXS as a powerful tool for understanding the structure and stability of concentrated, food-grade emulsions, providing key insights into their long-term performance.

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Comment la Composition des Matières Protéiques Végétales peut Influencer la Stabilité et la Rhéologie de Formulations Alimentaires ?

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Mots clés : protéines, formulation, lipides, émulsion, gel

Depuis plusieurs années, une demande croissante de la part des consommateurs pour des produits moins transformés, ayant un impact environnemental plus faible et dépourvus d'ingrédients chimiques artificiels tels que les conservateurs, stabilisants ou colorants est observée [1] . Une solution à ce problème pourrait être l'utilisation de protéines végétales dont les propriétés stabilisantes et gélifiantes sont reconnues [2]. Cependant, la complexité des systèmes en limite la maîtrise et constitue un obstacle à l'intégration de ces protéines dans les formulations alimentaires.

Ce projet ambitionne de réduire le gap qui existe entre la connaissance fondamentale qui peut être acquise sur des protéines et des lipides d'origine végétale et leur utilisation dans des maquettes de produits alimentaires. Diverses protéines végétales issues d'oléagineux et de légumineuses ont été étudiées sous plusieurs formes. Les solubilités des différentes protéines végétales dans une solution aqueuse ont été évaluées en fonction du temps et de l'agitation. Leur rôle stabilisant dans une émulsion a également été examiné à l'aide d'un granulomètre (qui permet de mesurer les distributions de tailles des gouttes) pour mieux comprendre l'impact de cette solubilisation. Enfin, les propriétés gélifiantes ont été étudiées spécifiquement à l'aide d'un rhéomètre. Leur application dans une maquette applicative a ensuite été abordée. L'objectif est de comparer un lait végétal existant avec une formulation où l'épaississant du lait est remplacé par les protéines. La corrélation entre le temps de solubilisation déterminé précédemment et les propriétés stabilisantes et épaississantes a été étudiée dans cette nouvelle émulsion.

Le cas d'un isolat de soja sera présenté. Celui-ci a montré de bonnes propriétés stabilisantes pour des systèmes simples, ainsi qu'une capacité à gélifier à haute température. Le transfert vers un système formulé a révélé que l'isolat de soja est un excellent substituant pour stabiliser l'émulsion de lait végétal, tout en permettant d'obtenir une rhéologie similaire à celle du lait commercial.

Cependant, les résultats varient en fonction de l'origine végétale et de la forme protéique, ce qui souligne la nécessité d'étudier ces facteurs pour mieux comprendre et contrôler les mécanismes de stabilisation et de gélification.

Cliché de microscopie optique du lait végétal stabilisé par l'isolat de soja

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Core-shell droplet generation in an on-chip temperature gradient

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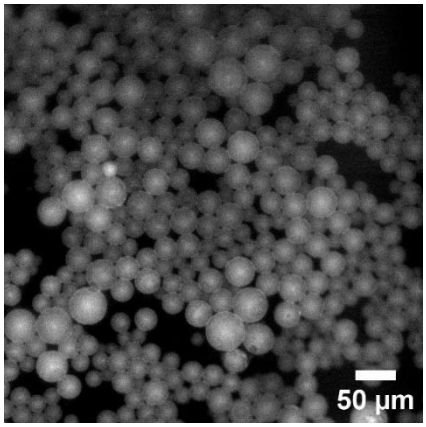
Keywords: Core-shell droplets, semi-solid crystal, microfluidic, temperature gradient, PDMS

Abstract: Core-shell droplets are commonly used for drug delivery in pharmaceutical products, flavor encapsulation in the food industry and perfume encapsulation in cosmetics. In this context, we focused on the processing and stabilization of emulsion droplets by adding a crystalizing surface-active lipid to the oil phase of an emulsion, involving the application of suitable temperature profiles in the droplet break-up and stabilization phases to ensure controlled particle formation. Glycerol monostearate (GMS) was selected because of its melting point above 60 °C, which makes it suitable as material for the droplet shells. We present a poly-(dimethyl siloxane) flow focusing microfluidic device integrated with a surface printed resistive heater, attached to a Peltier-cooling setup under an inverted research microscope for the generation of oil-in-water droplets coated by a GMS shell. The setup provided an on-chip temperature gradient from ~65 °C to 6°C over a distance of 5 mm. Droplets in a size range between 13 and 49 µm were collected and remained nearly unchanged over a time period of 5 days at 4°C. The size distribution of the collected particles is relatively large in comparison to conventional constant temperature droplet generators. We contribute this to temperature instabilities of the open loop temperature controller, leading to variations in viscosity and interfacial tension in the fluids, which influence the droplet size at the flow focusing junction inside the device. Improvements of this proof-of-concept setup by implementing closed-loop feedback are subject to further investigation.



Two techniques for direct visualization of how Pickering emulsions deform: rheo-microscopy and micropipette aspiration

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Keywords : Pickering emulsion, rheology, rheo-microscope, micropipette aspiration, food grade Pickering emulsion.

Abstract : Particle stabilized emulsions known as Pickering emulsions have numerous applications ranging from medicines to food (1). These Pickering emulsions show complex rheological behavior (2). The rheological properties of Pickering emulsions mainly depend on size, shape and interfacial properties of the particles used in the process of stabilizing the emulsions. Additionally rheological the properties can be altered by concentration of the particles and type and volume fraction of dispersed and continuous phases (2,3). Pickering emulsions prepared with Octenyl Succinic Anhydride modified starch, olive oil and water can serve as food grade Pickering emulsion. Rheological properties of Pickering emulsions are studied to some extent (4). However, the deformation of the Pickering emulsion and Pickering droplet needs to be explored further. Here we demonstrate two different microscopic methods to visualize and understand the deformation of Pickering emulsion droplet. With the help of a custom built rheo-microscope, we observe the shear thinning behavior of Pickering emulsion. From the micropipette aspiration technique, we measure the mechanical properties of the Pickering emulsion droplets. We show that their interfacial tension $\gamma \sim 10$ mN/m is much less than the water/oil interfacial tension without particles, for which $\gamma = 23.5$ mN/m. This decrease is due to the stabilization of the particles and we have the relationship $\gamma = \gamma 0 - \phi s W$, where ϕs is the surface fraction of particles at the interface and W is the reduction in surface energy due to the particles. From their dynamics of aspiration applying step pressures, typically $\Delta P \sim 4$ kPa, we can study the rigidity and viscosity of the Pickering layer. Finally, we unexpectedly observed a long-term flow of the emulsions in the pipette that might be associated to a rearrangement of the particles at the interface due to the applied pressure.

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From liquid to solid foams: towards new mechanically self-assembled gelatin foams

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Keywords: Edible foams, Gelatin, Hydrogel, Microfluidics

The generation of foams allows by a self-assembly of bubbles to create structured cellular materials, with applications in food industry, biomedical field, as well as for thermal insulation and mechanical cushioning. Numerous foams are obtained by chemical foaming or by mechanical incorporation of air, but those techniques do not allow a fine control of the foam morphology. Liquid foam templating is an alternative method which consists in producing cellular materials by introducing gas bubbles of controlled size into a polymer matrix, which then solidifies to achieve the desired structural characteristics [1]. We will focus here on hydrogel systems, and more specifically on gelatin-based materials. Such systems, studied in bulk in the literature [2], offer a large panel of properties, with potential applications in multiple fields including soft robotics and biomedical devices, combining resilience, biocompatibility and biodegradability, and can be used as an alternative to usual elastomeric materials.

Figure 1: Elastomeric gelatin foam obtained by liquid foam templating

We develop a system to generate homogeneous gelatin foams by liquid foam templating using microfluidic techniques, allowing the production of monodisperse elastomeric foams. Before solidification, modifying the foam structure by including intruders, such as fibers, can significantly alter its mechanical and functional properties, enabling new possibilities for tailored performance [3]. To reach new architectures and develop advanced foam materials with improved properties, we also start exploring the role of bio-based and/or edible intruders into those gelatin elastomeric matrices.

We expect that this work on model systems provides a path towards architected edible materials, with novel textures which might lead to different sensory experiences.

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Utilization of Insoluble Proteins from Wet Processing of Coconut for Stabilization of Pickering Emulsions

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Keywords (5 max): Pepper oleoresin; Essential oil; Pickering emulsions; Coconut byproducts; Protein particles

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Abstract : Edible particles, especially from plant sources, are of increasing interest for application in the development of food, and nutraceutical products. The present study deals with the utilization of insoluble protein particles (CIPP) from the wet processing of coconut for the stabilization of Pickering emulsions (PEs). Pepper Oleoresin (PO) and Pepper Essential Oil (PEO) are used as "oil phases". Dispersion studies were carried out using freeze-dried CIPP at different values of pH (3-10), temperature (30-60º C), and salt concentration (0.1-1M NaCl). The physicochemical properties of CIPP, such as wettability, particle size, surface potential, and thermal stability, were examined. The ultrasonication method is used to stabilize the O/W PEs. The optimal conditions for the ultrasonication method are identified as ultrasonication time-5 min, amplitude-40 %, and pulse mode 5s-ON /5s-OFF. The result indicated that the stability of PO and PEO emulsions increased with an increase in the concentration of CIPP. At low concentrations of CIPP (≤1% w/w), the coalescence of emulsion droplets resulting in phase separation is observed. At 2% CIPP, good stability is shown by both PO and PEO emulsions, with mean droplet sizes measured around 1 micron. The corresponding zeta potential are -25±1.3 mV and -29.4±1.6 mV, respectively. Other physical characteristics such as pH, viscosity, stability, and creaming index are examined for both PEs. The fluorescence microscopy studies revealed the adsorption of CIPP on the O/W interface. Overall, the CIPP have the potential to serve as a "Functional Ingredient" for producing "Surfactant-Free" Pickering emulsions.

Using coupled phase field models to predict microstructures of a compressible phase separation

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Keywords (5 max): Spinodal decomposition, GPU Computing, Meshless simulation

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Abstract : Understanding phase separation in mixtures is of great importance in fields such as biological cells, polymer composites, solar cells and many more. Spinodal decomposition is a spontaneous process which governs self assembly in both biological and polymer blends leading to the formation of membraneless organelles or material microstructures, for example.

In the case of polymer blends, the mixtures may be composed of materials with different densities, such that during phase separation, portions of the polymer (rich in materials with higher density) will shrink less compared to the lower density portions. This asymmetry changes the morphology compared to a transition from incompressible spinodal decomposition, hence produces a material with different characteristics as well as changing the bulk volume of the material.

To model this, we are investigating the morphology base on a compressible Floy-Huggins theory for the diffusive spinodal decomposition model coupled with hydrodynamics which enables shrinkage of the bulk material via the dynamics of a free surface, simulated via a custom mesh-free simulation framework on GPU.

In vitro digestion of food emulsions: milk, cream, and their vegetal substitutes

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Keywords (5 max): emulsion; droplet; milk; cream; digestibility

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Abstract: Plant-based substitutes are currently developed to mimic animal-based foods on the eve of the protein transition. Although their structural and textural characteristics are usually close to the original foods, their nutritional composition and quality are still not satisfactory. Notably, it is unclear how vegetal substitutes to milk products behave in the human gastrointestinal tract, and how their nutrients are released. To address these questions, we conducted a study to compare the behaviors of commercial food emulsions, namely cow milk products and some soy-based substitutes, in gastrointestinal conditions. Seven products were selected, of which the droplet size distribution and nutrient contents were characterized. Two milks (fortified in vitamin D3) and two creams with close characteristics were then studied during in vitro gastrointestinal digestion. Oil droplet interactions were monitored throughout digestion using optical microscopy, laser diffraction analysis, and electrophoretic light scattering. Lipid digestibility was quantified using HPLC-ELSD and pH-stat methods, and protein digestibility was quantified using the OPA spectrophotometric method. At the endpoint of intestinal digestion, the solubilization of lipolysis products and of vitamin D3 in bile micelles was measured. When comparing cow milk and soy-based products, despite having different compositions in fatty acids and amino acids, similar structural changes as well as similar lipolysis and proteolysis behaviors were observed during gastrointestinal digestion. Vitamin D3 stability and solubilization were also very close. These findings confirm that the main features controlling digestibility in these products are their physicochemical properties, including their physicochemical stability in gastrointestinal fluids.

Evaluating liquid foam properties of plant protein isolates as egg replacers

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Keywords (5 max): foamability, foam stability, plant protein isolates, egg replacers

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Abstract : (250 Words Max)

The increasing demand for plant-based alternatives to egg-derived foams necessitates a thorough understanding of the foaming properties of plant protein isolates in comparison to egg protein. This study investigates the foamability and foam stability of various plant protein isolates as potential egg replacers, utilizing foams generated via a Foamscan with a stirring method. Foamability was assessed through an overrun test, yielding the following ranking: egg albumen proteins> pea > soy > lentil ≥ lupin > faba bean > whole egg protein. Foam stability was evaluated based on the foam half-life time, resulting in the following order: egg albumen protein> faba bean ≥ soy > lupin > whole egg protein> pea > lentil. Beyond the interfacial properties of plant proteins, protein solubility emerged as a key determinant of foam stability. Additionally, the viscosity of bulk protein dispersions may influence stability by reducing liquid drainage. These findings provide valuable insights into the potential application of plant protein isolates in food formulations requiring foaming functionality.

Acid gelation of faba bean protein ingredients

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Keywords: plant proteins, thermal treatment, protein denaturation, chemical acidification, functionality.

Abstract: Increased interest in healthier foods is closely linked to growing environmental awareness and, as a result, the use of plant proteins is emphasized. In this context, pulses, which are rich in proteins, are very promising candidates and, particularly, there is a growing interest in the potential applications of faba bean (*Vicia faba* L.). Therefore, the objective of this study was to find the optimal conditions for the production of dairy like acid gels using faba bean protein ingredients obtained by dry fractionation from five different cultivars. To this end, the proteins were characterized by µDSC for their denaturation temperature, followed by screenings of thermal gelation conditions to determine the least gelling concentration (LGC). Finally, screenings of acid gelation conditions (using glucono-delta-lactone (GDL)) were performed to find the ideal GDL/protein ratio for acid gel formation. The proteins contained in the ingredients were denatured at temperatures ranging from 70 to 91°C. Thermal gelation conditions were then carried out at 95°C for 15 minutes, showing that faba bean cultivar influences the LGC. Subsequently, by analyzing the conditions for acid gelation of thermally denatured suspensions with 3% soluble protein (< LGC), the ratio of GDL to protein required to reach a pH of 4.6 at 40°C in 6 hours was found to be 20%. The thermic aggregates and the acid gels were also analyzed by microscopy to investigate their structure. These results highlight the potential of these ingredients in the production of acidified processed foods such as yoghurt and cream cheese.

Pickering Emulsions in Salad Dressings: A Physicochemical Perspective

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Presenter: Thang Tran

Keywords (5 max): Protein based Janus particles; Pickering emulsions, Lipid oxidation, Omega-3 PUFA fortification, Salad dressing

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Abstract : (250 Words Max)

Our study explores the potential of Pickering emulsions (PE) stabilized with Janus particles (JP) to enhance the physicochemical properties of PUFA-rich 2.5 wt% fish oil-in-water emulsions and examines their effects when used in fortified salad dressings. These JP were fabricated by electrohydrodynamic co-jetting technique with caseinate (1.0 wt%) and zein (4.0 wt%) and their bicompartmental structure was evaluated with CLSM and SEM. PE produced with JP were evaluated for physical stability with dynamic light scattering, creaming index. Lipid oxidation of these emulsions was measured by monitoring the formation of peroxide compounds and volatile compounds together with the depletion of tocopherols for 10 days. Emulsions stabilized with JP showed good physical stability with stable droplet size distribution with droplet size, [D4,3] around 1 μm compared to sodium caseinate-stabilized emulsions for which D[4,3] increased from 0.3 to 0.8 μm during 10 days storage. While peroxide formation and tocopherol depletion were similar in both, volatile compounds formed much slower in PE with JP, suggesting their role in inhibiting lipid hydroperoxide breakdown. Salad dressing was formulated with fish oil (2.5 wt%) in various forms: PE, conventional emulsions, and neat fish oil. These dressings were stored and assessed for physicochemical properties, odor, and appearance for 4 weeks. Evaluation of lipid oxidation was performed the same way as for emulsions while odor and appearance were assessed by a sensory panel every 2 weeks. This study provides insights into the physicochemical properties of PE as well as the sensory appeal of salad dressing fortified with these PE.

Are plant protein ingredients efficient egg white replacers in foams ?

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Keywords (5 max): plant proteins, foaming capacity, foam stability, foam texture, predictive modeling

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Abstract : (250 Words Max)

To meet the increasing demand for protein and environment sustainability, there is a necessity to support protein transition by expanding the range of plant-based protein products. Foams are particularly challenging applications as they required protein with high solubility, fast diffusion towards the interface, flexibility and interactions ability. Egg white proteins are often considered as reference proteins for foaming.

This study compared 7 plant protein ingredients (5 isolates – potato (2 proteins fractions), pea, soy and gluten; 2 concentrate – pea and soy) as egg white replacer in foams. Ingredient composition, physical and hydration properties of ingredient powders and foaming properties as well as foam texture have been characterized. Three ingredients out of the seven tested formed stable foams when rehydrated at minimum 3% (w/v) in water (2 potato protein isolates and 1 gluten isolate). The foaming properties of these ingredients and egg white were mainly explained by the ingredient composition and powder physical properties whereas the solution properties were not correlated with foaming properties. Optimization using experimental design and data analysis for protein content and pH were then performed on these ingredients. Predictive models were obtained for foaming capacity, foam stability against drainage, foam firmness, adhesiveness and cohesion as a function of pH and protein content for each ingredient. These models can be used by foam manufacturers to choose the best egg replacer considering the pH and the protein content of its application.

Milk fat globule's digestion by lipase followed at different scale

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Keywords (5 max): fluid interface, digestion, enzyme,

Abstract :

This presentation will focus on the digestion of milk fat globules (MFG), essential for newborn nutrition, and constituted by on an apolar core of triacylglycerides enveloped by a trilayered membrane. The major biological function of the MFG is to deliver energy to the mammal newborn, for that, the MFG has to be hydrolyzed in the gastro-intestinal tract by lipases, in successive steps. The lipases should interact with the MFG membrane and diffuse in the supramolecular object. The aim of this work is to determine the mechanism involved in the enzymatic hydrolysis along the digestive process.

Indeed, we used millifluidic cells designed to immobilize MFG and to inject successively each lipase involved in the digestion process (including change of pH). In addition, thanks to the UV-microscope developed on the DISCO beamline, the autofluorescence of tryptophan (and tyrosine) present in the lipase amino-acid sequences had allowed the protein observation without external labeling. The results show how each lipase interact with the MFG leading to its disruption.

In the other hand, the external leaflet of the trilayered membrane was reconstituted as a lipid monolayer on Langmuir trough. Ellipsometry, tensiometry, coupled with atomic force microscopy, allowed a better understanding of interactions between lipases and lipids at the molecular scale. Comparison with simplify lipid system,

Combination of these different techniques, of the studies at different scale and the use of lipid systems, highlight each step in the process of lipid digestion.

Predicting the swelling of starch granules using Flory-Rehner theories

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Keywords (5 max): Starch pasting, polymer swelling, microscopy

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Abstract : Starch pasting, i.e., the process by which aqueous dispersion of starch granules thicken upon heating, greatly influences the texture of a variety of consumer products. The current industrial paradigm is to use trial-and-error approaches to manipulate starch mechanics, which requires significant testing/investment when formulating new materials for the food and bioprocess industries. Here we discuss recent progress on developing physics-based models to predict the initial swelling of starch granules. We show that the dynamics of starch granule swelling can be captured by a diffusion equation of water into the granule, with the equilibrium water content captured by a Flory-Rehner theory of a crosslinked network that has the fraction of crosslinked chains varying as an empirical function of temperature. Having the cross-link density vary with temperature is important to capture equilibrium swelling at temperatures near and far away from gelatinization, although a single value of cross-linking can be used at high temperatures. The theory is compared against microscopy data of individual granule swelling for red bean, chickpea, green lentil, and yellow pea starches. We find that the experimental data for granule size versus time is able to be captured onto a master curve with appropriate shift factors. We use the Flory theory to understand how these shift factors are related to microstructural properties of the granules. At the end of the talk, we will discuss recent work on how to extend the Flory theory to include multiple ingredients (e.g., gums, sugars, etc.), with preliminary experimental data provided.

Understanding the stability of Pickering emulsions using on-chip microfluidics

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Keywords: Pickering emulsions, Microfluidics, Droplet coalescence, Stabilization

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Abstract: Particle-stabilized emulsions, commonly referred to as Pickering emulsions, offer superior stability, and functional versatility, compared to conventional surfactant-stabilized emulsions. While the majority of the work in this field has focused on densely covered Pickering emulsions, such emulsions are known to retain their exceptional stability even when the interfaces are sparsely covered with particles. In this talk, I will present our latest findings regarding the formation, dynamics, and stability of poorly covered model Pickering emulsions using a microfluidic platform, enabling precise design, production, and systematic analysis. I will show that the formed Pickering emulsions remain highly stable, over at least 12 hours, even with a surface area coverage below 3%. By directly visualizing the droplet interface at various stages, the exceptional stability is attributed to the highly spatially heterogeneous distribution of the adsorbed particles which exclusively form particle bridges at the contact point between the droplets. Remarkably, these bridges are assembled in the form of crowns between the droplet interfaces, as visualized by confocal microscopy. Lastly, I will discuss the different forces present during emulsification and how the assembly behavior of the adsorbed particles is dominated by hydrodynamic forces leading to a non-uniform particle distribution, corroborated by numerical simulations. In conclusion, our work provides an easy-to-access, controlled lab-on-a-chip platform to study Pickering emulsions, and gives important insights about the production and dynamics of Pickering emulsions via preferential interfacial localization of particles.
Reference: X. Shen et al., Understanding the stability of poorly covered Pickering emulsions using on-chip microfluidics, Adv. Sci., 2024, 2409903

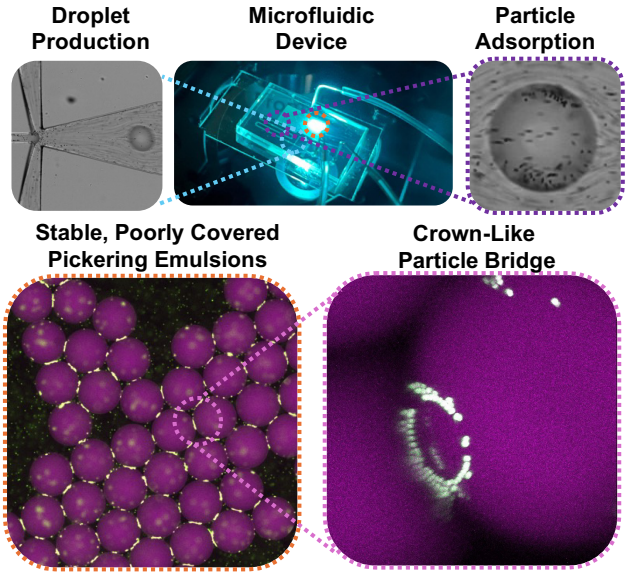

Figure 1: Working principle of microfluidic device and stabilization mechanism of poorly covered Pickering emulsions.

Kafirin-based Pickering stabilizers: tailoring interfacial properties

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Keywords (5 max): Kafirin nanoparticles; Interfacial behavior; General stress decomposition; Interfacial structure; Pickering stabilizer

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Abstract : (250 Words Max) Kafirin, extracted from sorghum, exhibits high surface hydrophobicity and can self-assemble into nanoparticles[1]. Kafirin nanoparticles have been used as Pickering emulsifiers, although their interfacial properties are largely unknown. We aimed to explore the mechanisms by which kafirin-based nanoparticles stabilize oil-water interfaces and emulsions. We systematically investigated the effect of gum Arabic (GA) and curcumin distribution on interfacial properties of kafirin nanoparticles, including their adsorption behavior and interfacial dilatational rheology in the linear viscoelastic regime and nonlinear viscoelastic regime. Additionally, we applied the general stress decomposition (GSD) method[2], to quantify the nonlinear responses in dilatational rheology, and relate these findings to changes to the interfacial network and resistance to changes in surface density. With GA addition, nanoparticles exhibited larger sizes, slower adsorption rates at oil-water interfaces, and formed stiffer interfaces. Curcumin distribution affected particle rearrangement but not adsorption behavior. Curcumin encapsulation or GA coating influenced particle interactions within the interfaces, leading to significantly altered nonlinear rheological properties: interfaces with modified particles derive their strength more from resistance against density changes compared to plain kafirin nanoparticles-stabilized interfaces. Strong in-plane interactions and denser interfaces were likely formed, making them more resistant to density changes. Interfacial microstructures were further confirmed with Confocal Laser Scanning Microscopy and Cryo-Scanning Electron Microscopy. These findings provide insights into the oil-water interfacial behavior of kafirin-based nanoparticles and their role in emulsion stabilization , which contributes to the better development of novel Pickering emulsion-based products in food, pharmaceuticals, and cosmetics.

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