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BOOK OF ABSTRACTS

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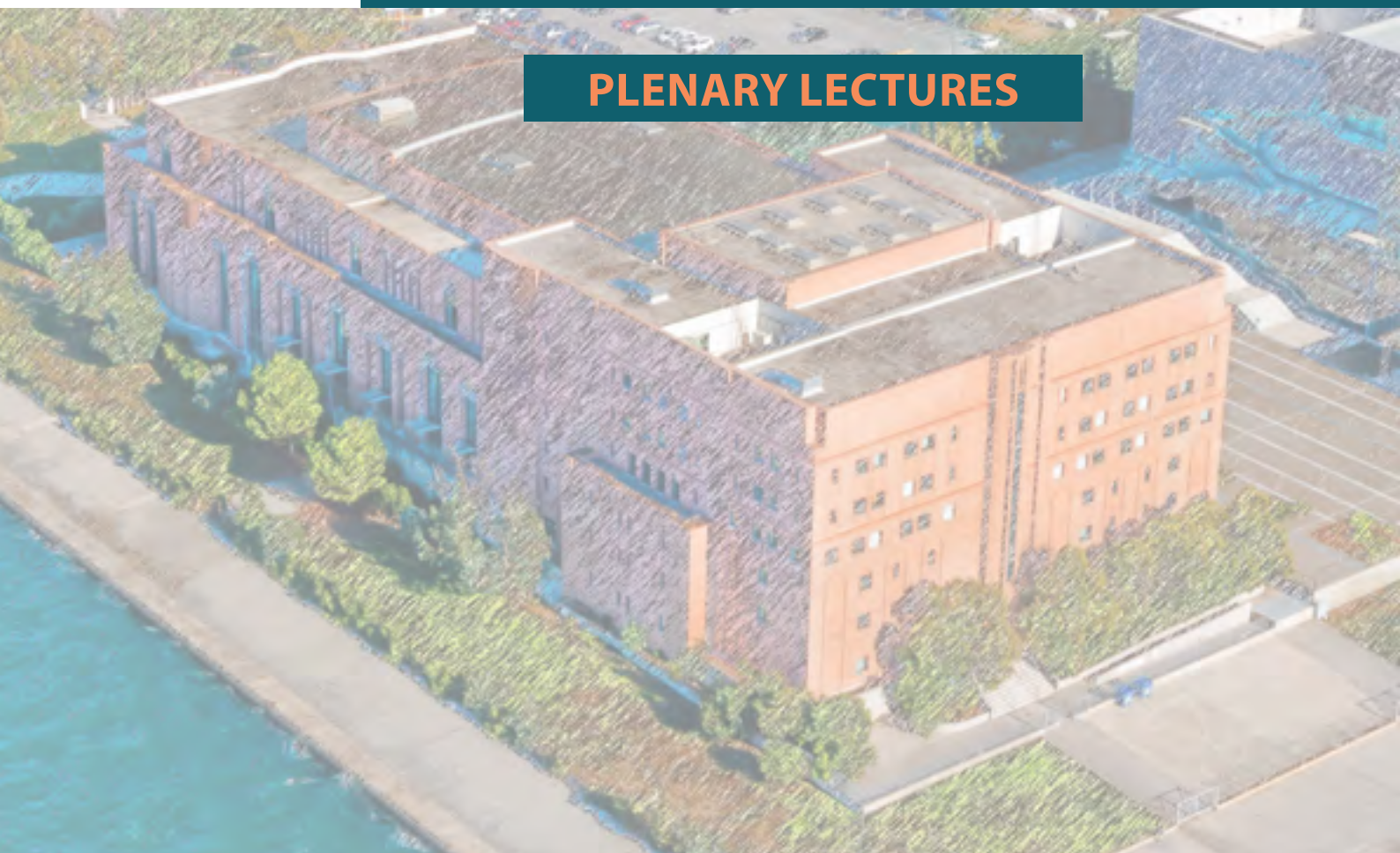

PLENARY LECTURES

Designing better plant protein foods through colloidal science

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ABSTRACT

To be able to design foods with plant-based ingredients one needs to have an in depth understanding of their structure and function relationship. But this is easier said than done. The complexity of the matrices requires relevant processing model systems and sample environments. Processing has to be re-designed as when using plant-derived proteins in formulations, often these ingredients do not measure up to current paradigms. Although the structure of the main legumins and albumins present in legumes and oilseed are well known, research is still needed to fully understand their properties during processing, and new experimental designs are needed to study their functionality, which take into consideration their low solubility, their colloidal properties and differences in dispersibility, and their complex composition.

Legumins and albumins are, in their native structure, in an insoluble form in the protein body. They can then be concentrated using milling and classification, or by wet extraction, to produce products of increasing purity. The processing history does not only affect the structure and colloidal properties of the protein but also its purity. Albeit it may be easier to predict their processing properties by using highly refined ingredients, one has to question the need of such refinement, based on a balanced evaluation of nutritional, functional and sustainability aspects. Compositional and molecular structure data needs to be integrated with spectral and microstructural data, as structural heterogeneities play a role in the functionality. Furthermore, advanced physical techniques such as light, X ray and neutrons can provide ensemble information at multiple scale, to complement rheological and microstructural data, the latter focusing on the meso-scale. This presentation will demonstrate the importance and the challenges of a soft matter science approach, and the need to use complementary techniques, simulations and models, hand-in-hand with experimental processing studies to be able to learn how to best design the foods of the future.

Acknowledgements: Funding for this program are provided by the Villum Foundation (award number 37759).

Complexity at micro and nanoscale. The coming era in colloidal sciences

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ABSTRACT

Complex systems are defined as those containing many interdependent constitutes which interact nonlinearly (1). Nanotechnology is an attractive scientific field in colloidal science that provides innovative formulation in food and food supplements. More specifically, nanotechnology exhibits a tremendous potential for improving the bioavailability of food supplements, nanoscaled formulations are being prepared and they are used to protect the products from degradation. The integration of Artificial Intelligence (AI) with nanotechnology will facilitate and optimize the development of nanomaterials and nanostructures, affecting several scientific fields and leading to a broad range of applications. The beauty of complex micro and nanoparticles and their lyotropic properties (i.e., different organization of molecules in the bulk formulation) relate to their morphological characteristics and follow the order of the natural harmony.

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Active Surface Agents: Active colloids at fluid-fluid interfaces

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ABSTRACT

We are advancing the concept of an *Active Surface Agent*, an active or self-propelled colloid trapped at fluid interfaces whose motion and trapping state can be designed to promote mixing and structure formation. This concept represents an important and largely untapped degree of freedom for interfacial engineering.
By understanding how biological swimmers move at fluid interfaces, we can develop design rules for artificial biomimetic systems to promote transport at fluid interfaces with broad implications in product design. Fluid interfaces are highly non-ideal, complex domains that impose constraints that alter swimming behavior. We study the bacterium *Pseudomonas Aeruginosa* (PA01) at fluid interfaces and characterize several distinct swimming behaviors. We find that the adsorbed bacteria are trapped in the interface with pinned three phase contact lines that significantly constrain their motion. In addition, surfactant adsorption alters interfacial mechanics. For colloidal swimmers, stress conditions require that the interface be a 2-D incompressible fluid, restructuring interfacial flows. We measure the flow generated by a swimmer at the interface in the pusher mode using a recently developed flow visualization method *correlated displacement velocimetry* and find a flow field with unexpected asymmetries. Hydrodynamic theory allows us to understand this flow field fundamentally and to explore its implications on mixing in the interface.

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Role of oil polarity on the interfacial phenomena of surfactants, proteins, and particles at fluid interfaces

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ABSTRACT

The formation of adsorption layers at fluid interfaces is essential in many industries, scientific disciplines, and biological processes. However, the effect of the oil phase on the structural transitions of proteins, adsorption of surfactants and particles, subsequent network formation, and layer strength at fluid interfaces has received little attention in interfacial experiments and emulsion design. This has been the cause for significant inconsistencies in the scientific literature, as experiments were often performed at arbitrary oils, which impeded the reproducibility and comparability as well as hampers the pathway to a generic description. Here, we summarize the effect of the oil phase on the adsorption, assembly, and interfacial rheology of surfactants, proteins, and particles at fluid interfaces and the resulting influence on emulsions [1-6]. Furthermore, we provide experimental guidelines for using oils in interfacial experiments, aiming to harmonize results and protocols in interfacial science.

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ORAL PRESENTATIONS

01. SUSTAINABLE FOOD COLLOIDS CLEAN, ENVIRONMENTALLY FRIENDLY, PLANT-BASED I

Towards the use of plant proteins for microencapsulation and functional foods

Selomulya Cordelia[1], Kim Woojeong[1], Ravindra Naik Rishi[1], Wang Yong[1]

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ABSTRACT

The ongoing development of plant-based ingredients and food products is crucial to ensure sustainable and healthy food systems. The consumption of plant-based foods are beneficial for the prevention of aging, cardiovascular diseases, and type-2 diabetes, although plant-based proteins often have poor functionalities and / or require extensive processing. Plant/dairy protein blends could be used as natural emulsifiers or as wall materials for encapsulation of bioactives in food powders, while alternative processing strategies can be applied to improve the functionality of plant proteins. Here we demonstrate strategies to improve plant protein functionality, including for uses as natural emulsifiers and carriers for nutraceuticals. Enzymatic cross-linking and polysaccharide addition to pea / whey protein blends are effective to stabilize emulsions and protect lipophilic bioactive compounds in oil-in-water emulsions and in spray dried microcapsules, by promoting protein unfolding and increasing ß-sheet in protein secondary structures [1-2]. Ultrasonic-assisted Maillard conjugation and spray drying can be used to generate a functional blend of conjugates and Maillard reaction products (MRPs) from amaranth seed proteins and Gracilaria secundata seaweed with notable improvement in solubility, emulsification, foaming capacity, surface hydrophobicity, and antioxidant properties [3]. Innovative and scalable technologies could expand the application of plant proteins in food colloids and promote their applications as food ingredients.

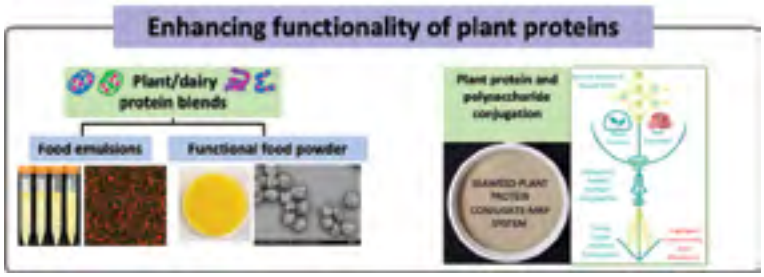

Figure 1. Enzymatic cross-linking between pea and whey proteins (L); Ultrasonic-assisted Maillard conjugation of amaranth seed proteins and red seaweed (R)

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Acknowledgements: This project was supported by ARC Discovery grant (DP200100642). The synchrotron-FTIR measurement was undertaken on the Infrared Microspectroscopy (IRM) beamline at the ANSTO Australian Synchrotron.

Coalescence of emulsion droplets stabilized by potato proteins within milliseconds as observed through microfluidic techniques: the effect of pH

Sreeprakash Arunitha K.[1,2], Bouhid de Aguiar Izabella[1], Schroen Karin[1]

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ABSTRACT

Production of food has a huge impact on the world as 25% of CO_2 emissions relate to this. An important aspect within food is the production of proteins that are essential for preventing malnutrition and creating healthy foods. Plant based proteins have great potential both as a healthy and a sustainable alternative to conventional animal-dairy based proteins. Depending on the animal source used, typically plant proteins would be 2-10 times more sustainable.

Although many protein sources are available, their techno-functional properties are not well known, at the time scales that they would experience during food production. In this presentation, we show results obtained with a microfluidic chip shown in figure 1. Oil and water are brought into contact under highly controlled conditions at the T-junction (light-blue rectangle), leading to droplets that move through a meandering channel and are allowed to interact in the coalescence chamber, where observations can take place at different positions along the chamber (medium, to dark-blue rectangle).

Among plant based proteins, potato are of specific interest because they are present in a side stream of potato starch production, and may become an important source of protein. The emulsifying property of two major fractions of the potato proteins – Solanic 200 and Solanic 300 are explored in this work. Coalescence of emulsion droplets was observed using the aforementioned microfluidic technique that allows to analyse the droplet interaction and coalescence at single droplet and milli second timescale. The pH is known to affect the emulsion stability and in this study, we quantify these differences within a pH range of 3-8 for both protein fractions. In general, the coalescence frequency is high at low pH, and decreases the pH closer to the isoelectric point and remains similar at higher pH. In the talk we will discuss the reason behind this behaviour.

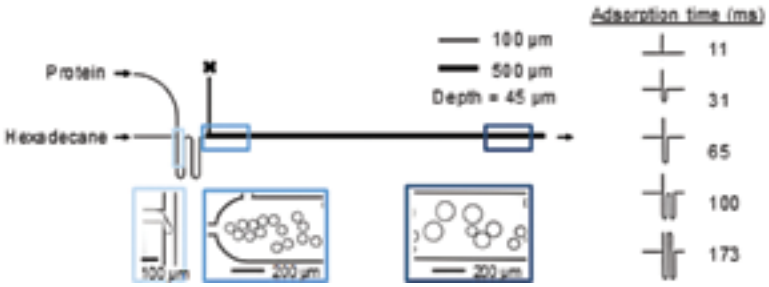

Figure 1: Schematic representation of microfluidic chip

Acknowledgements: The authors wish to thank Avebe for providing the potato protein samples.

02. SUSTAINABLE FOOD COLLOIDS CLEAN, ENVIRONMENTALLY FRIENDLY, PLANT-BASED II

Physicochemical and functional characterization of plant proteins for enhanced performance in plant-based cheese analogs

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ABSTRACT

Plant-based cheese analogs continue to grow in demand, despite failing to meet consumer expectations of functionality and nutrition, especially protein content. This research looked at the characterization of plant protein properties in soy (SP1), lentil (LP1), and two pea isolates (PP1, PP2), and their incorporation in cheese analogs to understand how they can be used to deliver sustainable alternatives with similar stretch, melt, and other critical attributes of dairy cheeses. Cheeses made with SP1, PP1, and PP2 displayed similar melting trends with spreads of 100-112% and moderate oil losses of 54-68%, while LP1 showed the least spread at 88% with no oil loss. SP1, PP1, and PP2 all had low solubility, high water-holding capacity, and low emulsification capacity, whereas LP1 also had low solubility but high emulsification capacity and low water-holding capacity. For rheological analysis of the cheeses, heating ramps were carried out from 20°C to 95°C. The elastic moduli (G') at 40°C and 90°C were compared to evaluate how different proteins impact the melting process. LP1 had a $G'_{40°C}$ to $G'_{90°C}$ ratio of 10.9 which was significantly lower than SP1, PP1, or PP2, with ratios ranging from 42.7-44.9. A greater ratio is ideal for mimicking the melting profile of dairy cheeses and indicates a greater breakdown of the solid structure during heating. Thermorheological differences were also seen when comparing tanδ values at 95°C, as SP1, PP1, and PP2 all achieved values over 0.64, indicating superior melt and viscous properties, whereas LP1 only reached 0.49. Although some softening occurs, LP1 maintains more structure during heating, suggesting greater starch interaction. Computed tomography was also carried out and LP1 displayed a highly different distribution of fat globules with a high density of small droplets, while SP1, PP1, and PP2 cheeses contained bigger globules with larger areas of phase-separated starch. The reduction in melt and oil loss for LP1 may be attributed to its greater emulsification capacity, forming smaller fat globules. In contrast, lower emulsification capacities observed for proteins SP1, PP1, and PP2 led to the formation of structures with lower heat-resistance and enhanced melting.

Acknowledgements: This research was financially supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) and Daiya Foods.

Protein-Polysaccharide Nanoparticle Complexation as a Novel Strategy to Reduce Protein Allergen Levels in Soy Milk

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ABSTRACT

The demand for plant-based diets is increasing; however, they pose problems if they contain allergenic ingredients, such as soybeans; therefore, it is crucial to find ways to reduce food allergenicity. Often, thermal and chemical hydrolysis treatments are not sufficient to achieve this goal; hence, novel strategies to reduce food allergen content are needed. As a proof-of-concept, it is hypothesised that soy protein allergens can be "captured" by forming nanoparticle complexes with polysaccharides, thereby reducing their levels in soy milk. In the present study, the solid particles were produced through soy protein:polysaccharide complexation using high-methoxyl pectin (HMP), low-methoxyl pectin (LMP), or gum arabic (GA), at different protein:polysaccharide ratios (w/w): 1:0.5, 1:1, and 1:2, and at different pH (2, 3.5, 4.5, and 6.55, which is the natural pH of the soy milk). Microscopy revealed that complexes were formed at pH 2 and 3.5, while zeta-potential measurements showed that soy proteins have an isoelectric point at around pH 4.5. No complexation was observed for HMP and LMP at pH 4.5. At pH 6.55, smaller nanoparticles were formed at 1:1 ratio than in other ratios. At the same pH, HMP and LMP complexes were smaller than 100 nm at 1:1 and 1:2 ratios. In the case of GA, nanoparticles were smaller than 100 nm at all pH values at 1:1 and 1:2 ratios. Using Zetasizer to determine the stability of the complexes through time, it appears that GA and HMP complexation at pH 2, 3.5, and 6.55 is driven by steric effects. Using SDS-PAGE, it was confirmed that glycinin and β-conglycinin levels were reduced after GA and HMP complexation at 1:1 and 1:2 ratios at pH 6.55. These results show that it is possible to "capture" soy protein allergens using polysaccharides at the pH of the soy milk with minimal number of steps.

Functionalisation of seaweed aqueous dispersions: interplay between polysaccharide solubility and cell wall physicochemical properties

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ABSTRACT

Seaweed-derived polysaccharides have been the object of study for decades, as they are widely used as texturisers in foods and pharmaceuticals. However, research on dispersions of polysaccharide particles, i.e cell walls, from seaweeds is still scarce. A better understanding of such systems could help fulfilling sustainability goals, as they make use of whole raw materials, reducing side streams, and also contribute to reach nutritional guidelines requiring a higher intake of dietary fibre.

We investigated aqueous dispersions of seaweed particles generated by thermal and shear treatments [1], and correlated rheological properties to cell wall nanostructural changes, which were analysed through small-angle X-ray scattering (SAXS) and microscopic technics. Brown algae polysaccharides, *i.e* alginate, fucoidan and laminarin, were solubilised during processing, significantly impacting the rheology of the continuous phase of the dispersions. However, their solubilisation was not always linked to alteration of the cell wall nanostructure, implying distinct reactivity and hydrocolloid solubility for different species. The rheological studies showed that stable gels could be achieved through high-shear treatments without the need of thermal step. Furthermore, our results highlight the recalcitrant nature of the cell wall, indicating a remarkable resistance to change under thermal treatments, which had minimal impact on the solubility of polysaccharides. These results underscore the potential for tailoring seaweed particle properties to optimise dispersion rheology. The intricate relationship between the rheological properties of dispersions and critical polysaccharide particle parameters like size, shape and charge was explored.

These findings enable the prediction, control, and design of structural and material properties in seaweed aqueous dispersions. By fine-tuning these properties, innovative and sustainable food products can be developed with enhanced dietary fiber content.

References: [1] Malafronte L. et al. Food Hydrocolloids 120, 106989 (2021)

Formation and structure of insoluble protein aggregates driven by calcium addition in different pea protein fractions as a function of pH

Amat Tiffany[1], Assifaoui Ali[1], Buczkowski Johann[2], Silva Juliana V.C.[2], Schmitt Christophe[2], Saurel Rémi[1]

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ABSTRACT

Pea ingredients are one of the main plant-based protein rich alternatives. Besides, it contains significant amount of minerals (calcium) and phytic acid (PA) molecules which can act as antinutrient [1]. The most represented protein family in pea is globulin which is further divided in 7S vicilin and 11S legumin fractions. The aim of this work was to study the interactions between these three protein fractions and both calcium ions and phytic acid at various pH conditions and to understand the effect of calcium addition on both the structure and the organization of the ternary system Protein/Ca/PA. Protein fractions were extracted by isoelectric point precipitation combined with a "salt" dissolution/precipitation purification method.

Protein extracts were characterized in terms of protein composition and structure (SEC-HPLC, SDS-PAGE electrophoresis, µDSC), conformation (intrinsic fluorescence), surface charges (zeta potential) and mineral content (PA and calcium). Calcium binding capacities were studied in protein dispersions (2.5% w/v) at pHs 4.5, 5.5, 6.5 and 7.5 by addition of $CaCl_2$ (Fig. 1). Free calcium contents were assessed by calcium sensor.

Protein complex formation and aggregate sizes were evaluated through turbidity and dynamic light scattering measurements. Results evidenced the pH influence on complexation phenomena which involved both pea protein and initial PA. Close to their isoelectric point (~5.0), proteins/PA are less charged and hardly bind calcium. Neutral pHs showed significant calcium binding capacities for all systems with formation of more or less dense protein aggregate phases. The better affinity of total globulin systems to bind calcium was highlighted and associated to less unfolded proteins (Fig. 1A). By contrast, 11S legumin dispersions were less likely to chelate calcium than 7S vicilin (Fig. 1B and C). Higher initial PA contents in total and 7S vicilin systems were supposed to intensify the formation of insoluble binary and/or ternary complexes between calcium, PA and proteins.

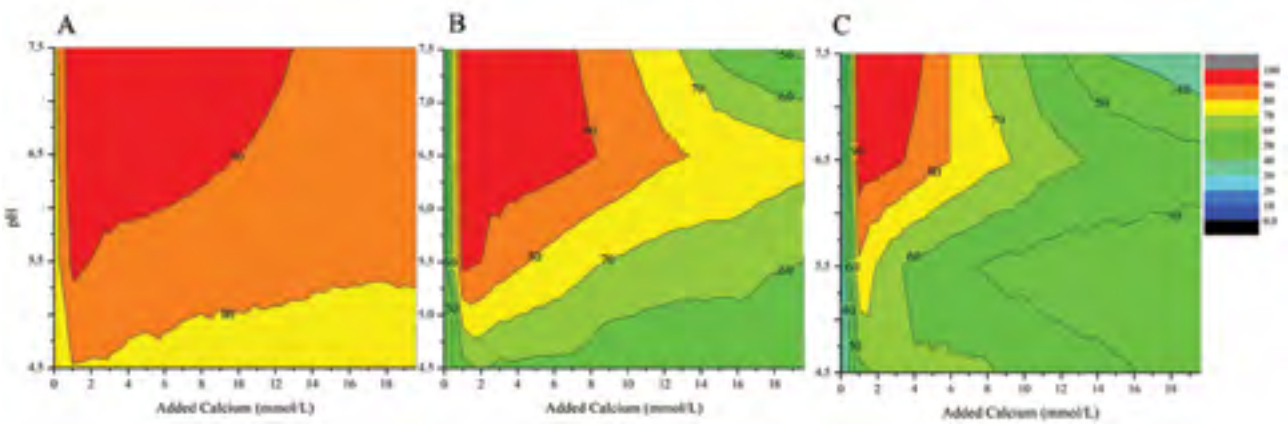

Figure 1: 3D graphics highlighting the percentage of bound calcium for pea globulin (A), 7S vicilin (B) and 11S legumin (C) as a function of added $CaCl_2$ depending on pH conditions.

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03. NEW METHODS AND NEW INSIGHTS IN FOOD COLLOIDAL SYSTEMS I

From production of food structures to their digestion and health effects: Microfluidics used in sustainable food design

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ABSTRACT

Humanity faces the huge challenge to supply a growing world population with sufficient and healthy food. To make this a reality we need to rethink how we produce food at large scale. This implies rethinking production 'on the land/in the greenhouse', fractionating raw materials, understanding their functionality during processes used in food production, as well as under digestive conditions to make the connection to health effects that can be created by smart food design.

Today's presentation will focus on investigation of processes that take place at micrometer scale, and even smaller scales, and often within very short times. These processes underlay the food structure that we get, but the dynamics thereof are very difficult to capture due to time and size challenges. Most examples that I will discuss use microfluidic tools to visualized these processes. For example, for formation of two phase systems such as emulsions and foams, and their digestion.

I hope to discuss with you how these techniques can contribute to more flexible use of ingredients. For example, replacement of animal-based products with their plant-based counterparts, and the use of biomass (e.g., leaves and stems) that are currently considered waist but can truly contribute to more sustainable food production practice. I am convinced that the techniques developed are ultimately used to do fast screening, will allow comparison of ingredients, link with digestion, and connect with more classic processing technologies (e.g., high pressure homogenization).

Coalescence of concentrated emulsions in microfluidic constrictions through avalanches

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ABSTRACT

Emulsions are usually subjected to flows during industrial processes e.g. while flowing through pipes, membranes, or nozzles. During these processes, emulsion destabilisation, such as break-up or coalescence of the droplets, may be induced by the flow. At high dispersed phase fractions, one local coalescence event can propagate leading to a cascade of coalescence events (i.e. a coalescence avalanche, Figure 1) and therewith destabilising part of the droplet assembly. In many cases, minimising flow-induced changes is crucial for maintaining the quality of emulsion-based products. In other cases, controlled coalescence is desired e.g. during phase-inversion. Since coalescence events rely on the interfacial physics at micro-scale, we developed microfluidic devices to study coalescence stability of concentrated emulsions flowing through constrictions *in-situ*. Furthermore, we investigated the underlying fluid dynamics by employing micro particle tracking velocimetry.

In a straight channel without constrictions, emulsions remained stable throughout the length of the channel. However, the presence of a constriction induced coalescence, and a cascade of coalescence events occurred against the flow direction. We experimentally demonstrate that interface relaxations result in the acceleration of the coalesced droplets. The accelerated retraction of the newly formed coalesced droplet towards a spherical shape, leads to drainage of the film between the coalesced drop and the trailing droplet therewith triggering a new coalescence event. This work thus provides novel insights into coalescence avalanches, and we unravelled the complex fluid mechanics responsible for the destabilisation of these flowing concentrated emulsions.

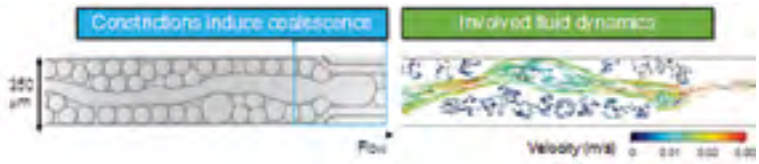

Figure 1. Example of a coalescence avalanche starting in the constriction and propagating in the upstream flow directions and the involved fluid dynamics

Thin films stabilized by plant-based proteins: Insights from the dynamic thin film balance technique

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ABSTRACT

The thin film balance (TFB) technique has been an invaluable tool in experimental soft matter since its first development by Sheludko in the 1950's. While it experienced a temporary decline in usage during the 1980s, it has now resurged as an essential tool for addressing critical research inquiries in the engineering of soft materials. However, its utilization for studying film stabilized by plant-based proteins has been rather limited, mostly due to the experimental difficulties associated with studying such systems.

In this presentation we will discuss how a recently developed version of the thin film balance, known as the bike-wheel microfluidic dynamic TFB [1], can be used to study free-standing foam films stabilized by various plant-derived proteins. We will specifically discuss how specific tests can be performed. We will then show results on the disjoining pressure and drainage dynamics of proteins of two different sources, namely of yellow pea albumins [2] and rapeseed cruciferins [3] and compare them with other well-studied animal-based proteins. Finally, we will show how the dynamic TFB experiments can provide significant insight regarding the structure of such proteins at the a/w interface and discuss how the latter affects physical processes that occur at the microscale, such as film rupture.

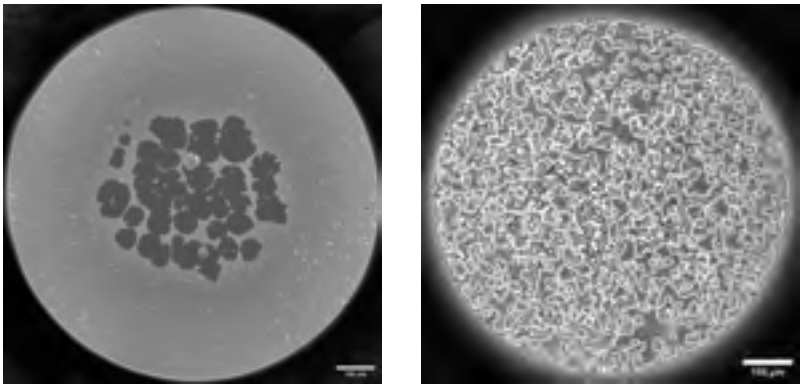

Figure 1. Microinterferometric images of foam films obtained using the dynamic TFB technique. *Left:* A film stabilized by yellow-pea albumins. *Right*: A film stabilized by rapeseed cruciferins.

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In situ visualization of microstructural re-arrangements during oleogelation

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ABSTRACT

Dynamic structural changes in food matrices are pivotal yet challenging to observe in situ at the microscopic level. Existing methods often overlook the microstructural transformations governing larger structural changes during food processes. Coherent anti-Stokes Raman scattering (CARS) microscopy, known for its chemical contrast capabilities, has emerged as a minimally invasive technique for static studies of food systems. This study explores the application of time-resolved CARS microscopy to capture real-time structural modifications during emulsion-templated oleogelation, a critical process in the creation of oleogels with potential applications in food and health.

During a six-hour drying period, the time-resolved CARS microscopy method enables the direct observation of dynamic changes in both fat and protein phases within the oleogelation process. Further, the microscopic evolution of the oleogel is quantified using image analysis. Specifically, the transition from an oil droplet emulsion with a continuous aqueous/ethanol phase, structured with agents like zein (a hydrophobic corn protein), to a self-standing oleogel with enhanced viscoelastic properties is investigated. This transformation involves intricate changes in the organization of the oil and protein phases, essential for understanding the structural evolution of oleogels.

While previous microscopic characterizations of emulsions and oleogels have been conducted, microscopic insights into the transition process are indirect. Direct observation using time-resolved CARS microscopy illuminates the elusive structural modifications occurring during oleogel formation, offering a foundational understanding crucial for future developments in the field of oleogels and their applications.

Understanding the intricacies of dynamic food processes through time-resolved microscopy not only enriches our comprehension of food materials but also paves the way for tailored structural advancements in food products.

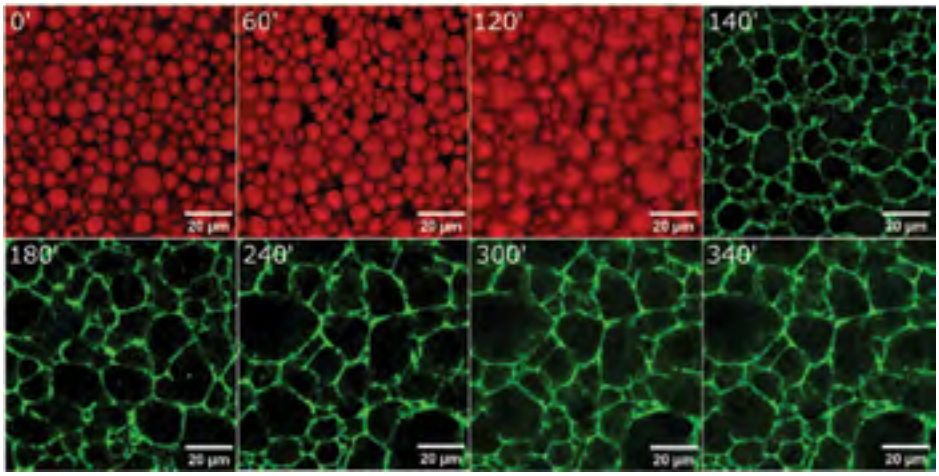

Figure: Time-evolution of emulsion-templated oleogelation showing the coalescence of fat droplets (red) and the creation of protein network (green).

Acknowledgements: The work was supported by Villum Foundation grant number VILLUM00025414.

Elucidating the Supramolecular Structure of Rapeseed Protein through Complementary Scattering Techniques

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ABSTRACT

Plant proteins, particularly those sourced from oilseeds like rapeseed, are promising candidates for replacing animal based proteins in the food industry, given their abundance, high protein content, and diverse functional characteristics. The rapeseed proteins differ in size, supramolecular structure, and are affected by the processing history. Novel techniques for gentler protein extraction have emerged, based on wet milling and separation of the native oleosomes. In these extracts, the protein suspensions are characterized by complex colloidal structures, which are challenging to investigate using conventional analytical techniques. In this study, rapeseed protein concentrates were obtained at either mild acidic or alkaline conditions, and the supramolecular structures present in the suspensions were investigated integrating microstructural data, size exclusion chromatography, small-angle X-ray (SAXS) and neutron scattering techniques (SANS). The suspensions contained pectin, and structural modifications after the addition of a commercial pectinase were also evaluated. SANS complimented with various contrast matching revealed that the colloidal protein complexes differed in sizes depending on extraction pH. When the extraction was carried out at acidic pH (5.7), one population of protein complexes with an approximate size of 4 nm were obtained. Conversely, at alkaline pH (8.5), two distinct populations emerged, with sizes of about 3 and 25 nm. Further investigation using SEC-MALS and SAXS showed that treating the suspensions with pectinase not only reduced the molecular size of pectins, but also changed the scattering intensity of the colloidal complexes extracted under acidic conditions. However, to fully understand the structural changes within the individual components of these complexes, more research is necessary. During the presentation we will therefore discuss the potential of complementing the scattering techniques with suitable fractionation methods for further advancing research in the area of complex colloidal systems.

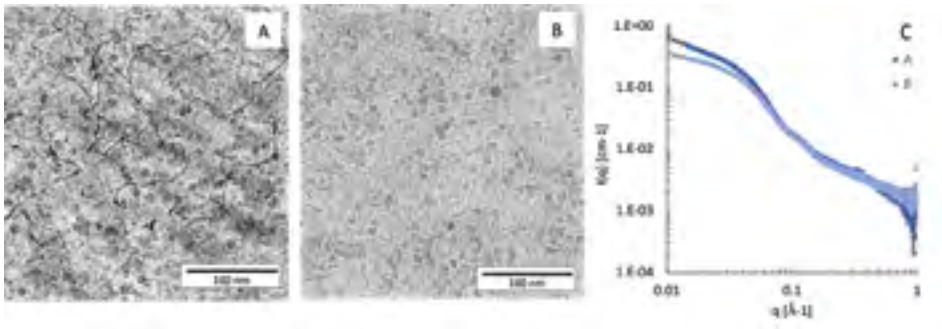

Figure 1. Microstructure of protein spheres and polysaccharide stands extracted at pH 5.7 without A) and with B) pectinase. Complementary SAXS scattering curves C)

Acknowledgements: The research was partly funded by the Center for Innovative Foods, CiFood at Aarhus University, and the Villum Foundation (award number 37759).

04. FOOD COLLOIDS IN NON-[OR CLOSE TO] FOOD APPLICATIONS NUTRACEUTICS, PHARMACEUTICS, PACKAGING, MEDICINE

Edible bio-based oleofilms from cellulose microfibrils - stabilized Pickering emulsions

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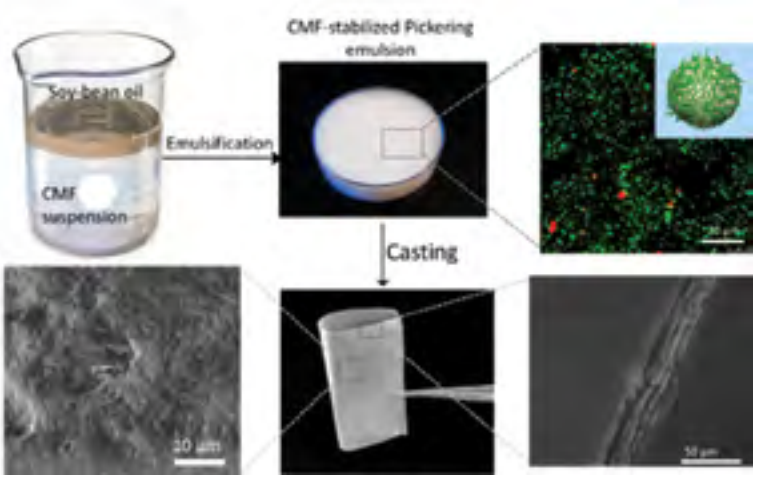
ABSTRACT

Low concentration oil-in-water emulsions stabilized by cellulose microfibrils (CMF) extracted from primary plant cell wall materials are used to prepare thin oleofilms by solvent casting. Bio-based translucent, and flexible composite films are obtained, with increased thermal stability (up to 300 °C) as the oil concentration increases. Examination of the structure of the films shows a multilayered structure where the oil phase is trapped between two layers of CMFs. The embedded oil significantly influences the mechanical and wetting properties of the films, confirming their potential for use in packaging systems. Encapsulation of curcumin in the films allows delivering of both antioxidant and antimicrobial functionality.



Impact of temperature-induced-swelling on surface properties of microgels based on oligo(ethylene glycol)

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ABSTRACT

Microgels based on oligoethylene glycol (OEG) comprise a new more biocompatible alternative to widely studied PolyN-isopropylacrylamide (PNIPAM) based microgels. Microgels swell or collapse in bulk as a response to external stimuli (temperature, pH..), however the impact of stimuli induced swelling on the surface behaviour of microgels remains unclear. An improved understanding of the surface properties of OEG-microgels is crucial to adequately develop stimuli responsive emulsions/foams with applications in biomedical and food sector.

Herein, we provide a detailed surface characterization OEG-microgels at the air-water interface including adsorption isotherms, kinetics and dilatational rheology in linear and non-linear deformation as well as spread Lanmguir-Pockels monolayers. Hence, we assess the impact of temperature-induced-swelling in surface conformation and mechanical response to dilatational deformation. We find that collapsed OEG-microgels protrude just further into the subphase, have faster kinetics and display a slightly lower dilatational response (Figure 1). Differences are discussed in terms of changes in surface hydrophobicity owing to network collapse at high temperatures. However, differences are subtle and hence shouldn't compromise their use as emulsion stabilizers, in contrast to PNIPAM based-microgels. Microgels show unique surface properties compared to proteins, polymeric or head/tail surfactants and still offer open questions regarding the underlying mechanisms governing their surface behavior. This work provides new insight into relevant surface properties to guide future design of stimuli responsive emulsions with food applications.

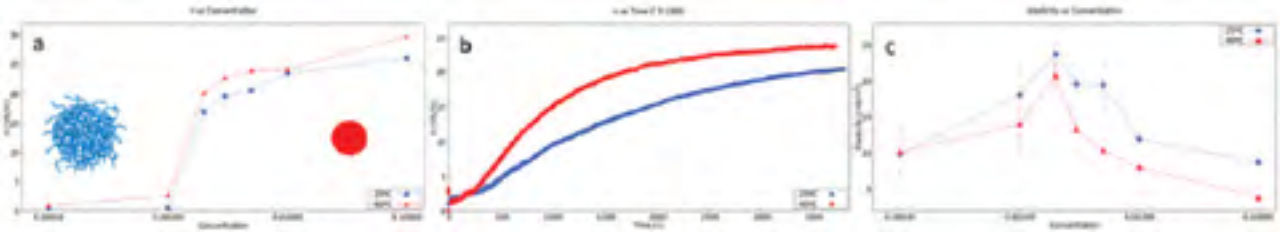

Figure 1. (a) Surface Pressure versus concentration (b) surface pressure versus time, 0.01 % (c) Dilatational elasticity versus concentration of adsorbed OEG-microgels at air-water interface, swollen (25 °C, blue) and collapsed (45 °C, red).

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Acknowledgements: This work was funded by MCIN/AEI/10.13039/501100011033 and by "ERDF A way of making Europe; project PID2020-631-116615RAI00 and RED2022-134276-T.

Ethylcellulose oleogel as the potential controlled release delivery system

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ABSTRACT

Oleogels are commonly formed using an oleogelator(e.g., ethylcellulose(EC)), which could form a self-assembly network and entrapping oil. In this work, we investigate the potential of EC oleogels as a controlled release system for probiotics. The physical properties of EC oleogels were well studied using a rheometer and texture analyzer. Nevertheless, using in vitro digestion models, we have found out that EC oleogels can retard lipolysis of the entrapped oil substantially(low-oil-release) either with a higher molecular weight of EC or with a higher concentration of EC. For example, using 10% EC cp300 (high viscosity) in the oleogel resulted in less than 40% completion of lipolysis after 2 hours. This is interesting for probiotics as this might increase the survivability of the bacteria in the GI tract, where bile salts are a major challenge. However, the high retarding effect from EC oleogels also means a too-low release of the probiotics. Therefore, we have continued to investigate how to control the release pattern of these oleogels. Furthermore, results show that bacteria have high survivability both in EC oleogel formulations and under gastric conditions. Structural information obtained by SAXS shows that there are long-range and short-range structures in the oleogels, which can be related to the rheological properties of the oleogels, and further to the digestion properties of the oleogels. In conclusion, with a better understanding of EC oleogel structure and digestion profile, EC oleogels might be a promising formulation strategy for probiotics.

Acknowledgments: This research is a part of NextBioForm, an industrial consortium supported by the Swedish Governmental Agency for Innovation System (VINNOVA).

Food amyloid fibrils are safe nutrition ingredients based on in-vitro and in-vivo assessment

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ABSTRACT

Food protein amyloid fibrils have superior technological, nutritional, sensorial, and physical properties compared to native monomers, but there is as yet insufficient understanding of their digestive fate and safety for wide consumption. By combining SDS-PAGE, ELISA, fluorescence, AFM, MALDI-MS, CD, microfluidics, and SAXS techniques for the characterization of β-lactoglobulin and lysozyme amyloid fibrils subjected to in-vitro gastrointestinal digestion, here we show that either no noticeable conformational differences exist between amyloid aggregates and their monomer counterparts after the gastrointestinal digestion process (as in β-lactoglobulin), or that amyloid fibrils are digested significantly better than monomers (as in lysozyme). Moreover, in-vitro exposure of human cell lines and in-vivo studies with *C. elegans* and mouse models, indicate that the digested fibrils present no observable cytotoxicity, physiological abnormalities in health-span, nor accumulation of fibril-induced plaques in brain nor other organs. These extensive in-vitro and in-vivo studies together suggest that the digested food amyloids are at least equally as safe as those obtained from the digestion of corresponding native monomers, pointing to food amyloid fibrils as potential ingredients for human nutrition.

Modifying proteins to make hollow or solid microparticles

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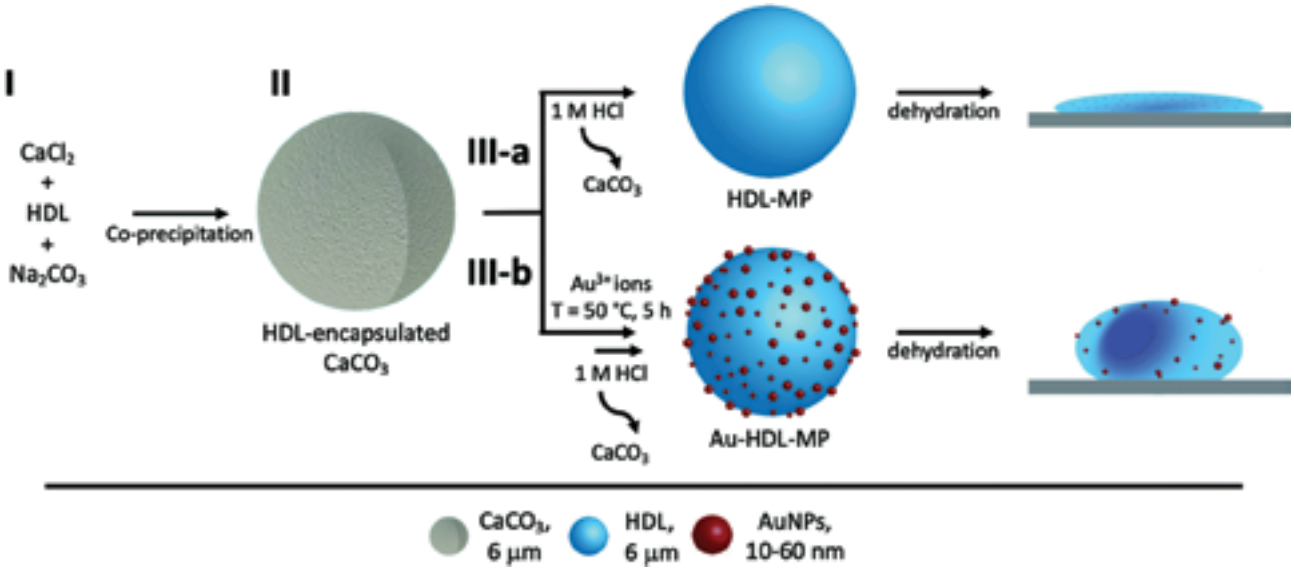
ABSTRACT

Hollow microparticles are of great relevance in the materials industry for a wide range of applications, such as catalysis, coatings, and delivery of theranostics. Here, we report the formation of hollow and solid microparticles through the assembly of proteins in $CaCO_3$ templates. Hollow microparticles can enhance the capacitance due to their large interior void. For preparing microparticles, polymers have been assembled into spherical structures through the use of porous CaCO3 templates, followed by polymer cross-linking and selective template removal. However, this often results in the formation of microparticles with a solid core. Here we use proteins with different aggregate size distributions (<10 nm or >100 nm) to either form solid or hollow microparticles. Proteins were mixed with CaCl2 and Na_2CO3 solutions, which form $CaCO_3$ microcrystals (with 20–60 nm pores) with encapsulated proteins. We show that small protein aggregates are uniformly distributed into the $CaCO_3$ templates. However, larger protein aggregates accumulated at the template edges. Au^{3+} ions were then added, which oxidize and cross-link proteins and are reduced to form gold nanoparticles (AuNPs). After the removal of the templates, the small proteins formed solid microparticles and the larger protein aggregates hollow microparticles. This method of fabrication of solid and hollow protein microparticles, with embedded AuNPs, could be used for generating biomaterials with a broader range of applications, such as hosting molecules and multimodal imaging due to the presence of the AuNPs.



Advanced pH-Responsive Rhamnolipid self-assemblies for food and pharmaceutical applications

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ABSTRACT

The problem of bacterial resistance to conventional antibiotics at acidic pH has persisted for a long time. [1] Hence, an urgent need to develop alternative biocompatible, sustainable, and pH-responsive novel antimicrobial biomaterials is gaining considerable attention during last few years.[2] Herein, the rational design and characterization of a biocompatible pH-responsive antimicrobial material is demonstrated upon combining microbial-derived rhamnolipids (RL) and food-grade glyceryl monooleate (GMO).[3] The supramolecular materials are optimized for their antimicrobial and biofilm inhibition activity in acidic pH environments of acute wounds (Figure 1). While RL alone phase separates below pH 6.0, its integration into dispersed GMO particles forms a colloidally stable dispersion. The structural alterations due to composition and pH changes are investigated using small-angle X-ray scattering, cryogenic transmission electron microscopy, and dynamic light scattering. The structures evolved from Im3m type cubic phase to vesicles in these nanomaterials. In vitro biological assays demonstrated that RL/GMO dispersions specifically targets Gram-positive bacteria Staphylococcus aureus (S. aureus) and methicillin-resistant S. aureus (MRSA) and prevent their biofilm formation at pH 5.0 while being inactive at pH 7.0. Moreover, these materials show no activity against various Gram-negative bacteria at both the pH levels. The nanomaterials are cytocompatible towards human dermal fibroblasts. The findings overall help in fundamental understanding of lipid self-assembly and the formulation of lipid-based biomaterials for potential bio-based antibacterial solutions. The results further outline a promising strategy to discover potential interactions between RL and mucin, offering new opportunities in developing innovative nutrient and drug delivery systems to address unmet clinical needs.

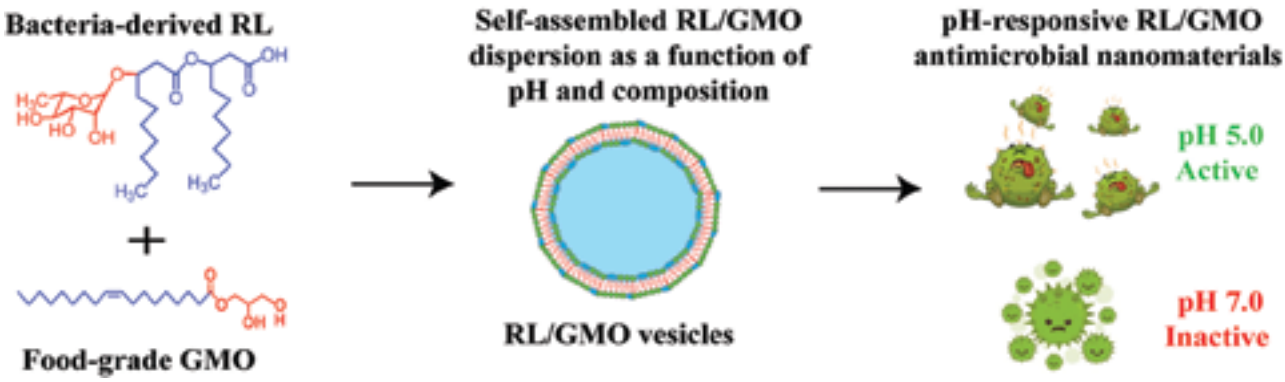

Figure 1. An illustration showing formation of self-assembled RL/GMO vesicles characterized by SAXS which is antimicrobially active against Gram-positive bacteria and prevents their biofilm formation at pH 5.0.

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[3] P. Kadakia, J. Valentin, L. Hong, S. Watts, O. A. Hameed, M. Walch, S. Salentinig, Advanced Healthcare Materials, 2023.

Acknowledgements: This work is funded by Swiss National Science Foundation through project no. 192051. The authors thank the SAXS beamline at the Elettra Synchrotron.

05. COLLOIDS IN HUMANS DELIVERY SYSTEMS, BIOAVAILABILITY, DIGESTION AND ORAL PROCESSING I

Heterogeneous Solubilization within Lyotropic Liquid Crystals

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ABSTRACT

This study explores the impact of sodium diclofenac (Na_DCF) on a glycerol mono-oleate (GMO)-based lyotropic liquid crystal. Na_DCF was solubilized in a GMO/tricaprylin/water emulsion, forming a reverse hexagonal mesophase at 2-5 wt% Na_DCF and an intermediate ribbon mesophase at 6-9 wt% Na_DCF. These structural changes affected the system's storage modulus (G'), structuring enthalpy (ΔH_{str}), and structural diffusivity (T_2/T_1).

Notably, the coherent scattering domain within the hexagonal mesophase remained relatively constant (±20nm), suggesting a shift in the proportion between hexagonally-oriented rods and non-oriented micelles due to Na_DCF solubilization. Moreover, Na_DCF's preference for solubilizing at enhanced critical packing parameter interfaces was demonstrated by an immediate 35% increase in the microviscosity of 5-doxyl stearic acid at 1 wt% Na_DCF. This selectivity in Na_DCF solubilization was further corroborated by different anisotropic to isotropic ratios of sodium (66%) and deuterium (13%) at 1 wt% Na_DCF.

The study established a linear correlation between the Higuchian release constant and the drug load ($R^2 > 0.99$), indicating that the release rate primarily depends on the compound's solubility and the free energy per unit area (γ) of the solubilizing interface. Conversely, the system's entropy, symmetry, and order minimally impact Na_DCF's release. As the driving force for heterogeneous solubilization arises from the local increase in micellar free energy (γ), it maintains a constant release driving force despite structural transitions affecting the matrix.

The results presented in this paper will appear in the Ph.D. dissertation of E.G. in partial fulfillment of the requirements for the Ph.D. degree in Chemistry, The Hebrew University of Jerusalem, Israel.

Effect of processing conditions on the digestibility of potato protein isolate and rapeseed oil in a complex food matrix

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ABSTRACT

Potato proteins have recently gained considerable attention due to their technological properties, good amino acid profile and low allergenicity. However, it is crucial to comprehend the intricate process of digestion of these proteins, as it directly affects their nutritional properties. In this research, we aimed to understand how different processing conditions affect potato protein digestibility in complex food matrices. Physically modified (homogenized at 500 bar, 5 minutes) and heat treated (90 °C, 15 min) potato protein isolate solutions (3 wt %) were examined as an emulsifier in stabilizing 10 wt% rapeseed oil-in-water emulsions. High-pressure homogenization was found to significantly decrease PPI particle size distribution, while heat treatment induced gelation, thus increasing particle size.

Characterization by gel electrophoresis, size exclusion gel chromatography showed distinct protein distribution patterns, indicating different protein breakdown mechanism. Lipolysis was characterized by measuring free fatty acids (nmol/µL) in undigested, gastric and intestinal points of all samples. No significant differences ($p<0.05$) were detected before digestion. However, the amount of free fatty acids released was significantly higher than other samples under gastric (10.6 ± 0.2) and intestinal (140.2 ± 1.9) conditions. During the in vitro digestion of the nanoemulsions, the modified potato protein isolate exhibited considerably greater lipid digestibility due to its increased interfacial area in smaller droplets compared to those containing unmodified PPI. This indicates that high-pressure homogenization is suitable to create, stabilize and enhance digestibility of potato protein nanoemulsions. The study underscores the importance of *in vitro* screening for food product development and contributes to our search for a new generation of nutritious and sustainable foods, by demonstrating the significance of processing history and food structure in determining the impact on digestion and peptides distribution.

Tailored design of polyelectrolyte complexes (PECs) for encapsulation of low molecular weight bioactive peptides (BAPs)

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ABSTRACT

Our study focuses on improving the encapsulation and controlled delivery of bioactive peptides (BAPs) by exploring electrostatically mediated macromolecular aggregates of two polysaccharides. Current systems often suffer from premature cargo release due to factors such as the action of digestive enzymes and pH swings. To address this, we have developed Polyelectrolyte Complexes (PECs) from non-digestible chitosan (Cs) and sodium alginate (Alg) via a one-step mixing process. The resulting PECs were characterized via dynamic light scattering (DLS), mixed-mode phase analysis light scattering (M3-PALS), small-angle X-ray scattering (SAXS) and scanning electron microscopy (SEM). Subsequently, we used two PECs, one with an excess of Cs and another with an excess of Alg, to encapsulate low molecular weight (M_w) fish BAPs, quantifying their encapsulation efficiency (EE) and release patterns at both gastric and intestinal pH levels via HPLC-UV/Vis analysis. The morphology of the loaded PECs was also investigated via transmission electron microscopy (TEM).

We found that the PEC hydrodynamic radius (R_h) depends on the charge ratio (n-/n+). At low n-/n+ ratios (0.1 to 0.6), R_h reduced from approximately 800 to 300 ± 50 nm, indicating more compact structures. The zeta potential also changed with n-/n+. The role of Alg M_w was explored, supported by SAXS results and provided insights into the structural diversity achievable using this simple complexation method. Importantly, our PECs demonstrated EE values of 80 to 85% and controlled release of less than 10% at pH 2.0 and less than 20% at pH 6.8, after 3 h. TEM analysis showed that the loaded PECs ranged in size from less than 50 nm to over 10 µm.

This research highlights the potential of such PECs as effective carriers for low M_w fish BAPs, offering controlled release and enhanced protection against premature degradation. It represents a significant advancement in BAP delivery and encapsulation technology.

06. COLLOIDS IN HUMANS DELIVERY SYSTEMS, BIOAVAILABILITY, DIGESTION AND ORAL PROCESSING II

Polysaccharide Microgels for Design of Biomaterials

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ABSTRACT

Microgels (MGs) have attracted tremendous attention in drug delivery, disease diagnostics and tissue engineering, due to their unique properties like variable size, adjustable mechanical properties and adaptability to biological systems. In particular, 3D crosslinked network of MGs enables capacious loading and controlled release of small molecules, such as drugs, proteins, nucleic acids as well as large objects like cells. However, many microgels are synthesized from synthetic polymers, which are not degradable and sometimes not biocompatible, what limits their application in medical field.

This paper will focus on the use of natural biomacromolecules polysaccharides (chitosan, pectin or dextran) as building blocks for the synthesis of tailored microgels. Different methods for chemical and enzymatic modification of polysaccharides to introduce the reactive groups (epoxy, acrylate, azide, alkyne, etc.) will be described.

Different synthesis approaches to obtain polysaccharide-based microgels can be realized in miniemulsion or microfluidic droplets to fabricate colloids with controlled size (100 nm – 100 µm), adjustable pore size and functional surface.[1,2]

The applications of polysaccharide microgels in drug delivery (carriers for antibiotics delivery)[3] and tissue engineering (microporous annealed particle scaffolds (MAPS) for cell proliferation)[4] will be discussed.

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Colloidal interactions during the oral processing of soft foods: From thermodynamics to texture

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ABSTRACT

The oral processing of hydrocolloid-based foods involves the mixing of their structural components (typically polysaccharides and/or proteins) with saliva. The molecular-level interactions (based on thermodynamic and kinetic measurements) between the structural components of saliva (mostly mucins) and those of food lead to colloidal-level alterations in the bolus (aggregations, phase separations), generate macroscopic-level phenomena (precipitations, shear and extensional rheology, tribology) which in turn determine texture and flavor.

This presentation involves a critical assessment of data collected in the form of phase diagrams of binary or ternary dispersions/solutions comprising structural proteins/polysaccharides (acting as model soft food structural ingredients), mucin (acting as model saliva), and other ingredients (e.g. polyphenols). The conclusion is that mixing a hydrocolloidal food with saliva induces drastic concentration and phase changes in the food matrix; these can be traced to the molecular-level interactions between the food structural macromolecules and mucin, with marked implications in shear rheology, extensional rheology and tribology. These strongly affect the perceived texture and flavor profile of a hydrocolloid-based food. The above are discussed under the light of the functionality of saliva in health, along with the implications of saliva deficiency (as in the case of xerostomia), as challenges for the design of salivary substitutes and for personalising nutrition.

Stability, acceptability and bioaccessibility of DHA and EPA incorporated in plant milk

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ABSTRACT

Omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) are imperative for general biological functions and may be involved in prevention and treatment of various diseases. These fatty acids are primarily found in fish and fish oil but have also been extracted from algae and genetically modified organisms such as yeast and oilseeds.

Despite the benefits, fish, and consequently EPA and DHA, consumption is below recommended levels suggesting the need for new strategies to increase consumption. In the following studies, fish and algae oil were emulsified and incorporated into plant-based milk beverages. The beverages were analyzed for their physicochemical stability, comparing three different beverage bases, soy, oat, and almond, and water. It was found that oat and almond milk were the most physically stable to emulsion separation and sedimentation, and soy and oat milk were most resistant to oxidation.

The consumer rejection threshold of fish and algae oils in the three-plant milk beverages was found to be 0.2-0.4% when added to oat and soy milk without causing consumer rejection. Almond milk was found to be a poor vehicle for these oils, as any concentration led to rejection.

From the results of the previous studies, soymilk was chosen as the EPA and DHA vehicle used in a pilot bioavailability study. The goal of this study was to evaluate the bioavailability and distribution of EPA and DHA from algae oil in two different matrices, a plant-milk beverage and conventional oil capsules. In this study, compliance was shown to be over 95% to the intervention and subjects found the beverages moderately acceptable, with no difference noted between a control and algae oil fortified soymilk. No major adverse events were reported and symptoms from soymilk consumption were mild and short lived. Bioavailability data analysis is ongoing and some preliminary data will be presented.

07. NEW METHODS AND NEW INSIGHTS IN FOOD COLLOIDAL SYSTEMS II

Isotropic liquid state of triacylglycerols: The starting point of fats and oils crystallization

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ABSTRACT

The current research focuses on the molecular organization of lipids in the isotropic liquid state, starting with pure model systems and proceeding with realistic complex models. The organization was explored using experimental structural, thermal, and mechanical analysis in combination with computational analysis based on molecular dynamics simulations. Initially, the liquid organization of tristerin and triolein was studied as models for saturated and unsaturated triacylglycerols (TAGs), respectively. More specifically, we examined the inter- and intra-molecular interactions to determine the conformations of the molecules and their arrangements in the bulk liquid. The results obtained from these analyses allowed to resolve a long-lasting debate concerning the organization of pure TAGs in the isotropic liquid state. The MD simulations showed the existence of four different conformations of TAGs at isotropic liquid state, following the abundancy order: trident (Tr) > chair (Ch) > propeller (Pr) > tuning-fork (Tf), which changes constantly at a high conversion rate positively correlated to temperature. Surprisingly, preferability analysis showed that Tf will preferably pair only with Tr although Tf is the preferable conformation in most crystal polymorphs. Moreover, we established the relation between the molecular organizations in the liquid state and the crystallization process. Such experimental and computational toolbox was further used to study complex processes such as cocoa butter (CB) crystallization. Clustering analysis showed that, on average, every molecule has two neighbor molecules, suggesting that the clusters have elongated shape which is different than the crystalline lamellar structure, formed at solid state. In-depth analysis of the molecules inside the clusters demonstrated that the probability of the formation of a POS nucleus is higher than the probability of the formation of POP and SOS nuclei which is later resulting in a crystal structure similar to POS crystal pattern.

Lipid-Polymer Hybrid Nanofibres: Responsive Nanostructures and Controlled Functions

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ABSTRACT

The biological functions of advanced materials are highly correlated with their mechanical properties through their microscale morphology, nanoscale hierarchy, and the anisotropy. In particular, the fibrous network of polymer-based hydrogels can offer smart solutions for current challenges in designing artificial extra cellular matrices (ECMs) nevertheless, the multiscale structural hierarchy of nanofibers must be well controlled during processing.

The structural morphology of biopolymer networks in native ECMs is known to play important roles in cellular adhesion and proliferation, controlling the tissue homeostasis. The ability to engineer ECMs using soft materials with tunable hierarchy and high mechanical stability yet, using non-chemical modifications remains a great challenge in engineering novel biomaterials.

In this presentation, I will discuss the recent advances in fabrication of novel hybrid lipid-polymer scaffolds in my group. I will particularly present how unique nanostructures from lipid self-assemblies can be incorporated into biopolymer networks by electrospinning. [1,2] I will also discuss the state of the art in-situ analytical methods, e.g. scattering, for understanding the structure-function correlation in hybrid scaffolds.

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Exploring the relationship between structural characteristics and functional properties of textured vegetable proteins

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ABSTRACT

Meat analogues are pivotal in the transition to more sustainable protein sources. To mimic the fibrous nature of meat, textured vegetable proteins (TVP) are often used, which are obtained from extrusion processes. TVP properties significantly impact the quality of meat analogues, as they influence the amount of water absorbed during processing and released during consumption. Therefore, TVP plays a crucial role in the juiciness of meat analogues. Limited information is available on how the structural features of TVP (porosity, pore size, wall thickness, etc.) impact its functionality. The objective of this study was to investigate the effect of the structural characteristics of a wide range of TVPs on rehydration behaviour and the properties of meat analogues prepared from the TVPs (serum release and texture characteristics).

The porosity, pore size, wall thickness and wall density of thirteen commercial TVPs were quantified using X-ray microtomography in combination with image analysis (Figure 1A). Water absorption by TVP can be described by a double exponential model (Figure 1B). Thicker walls promoted water absorption during the early stages of rehydration. At longer time scales, the water absorption capacity and water holding capacity (WHC) were higher for TVPs with thinner walls and higher porosity. Our results suggest that water is absorbed by the TVP walls driven by capillary forces induced by nanopores within the walls.

When TVPs were incorporated in meat analogues, significant differences in WHC and textural and rheological properties were observed, underscoring the important role of TVP properties on the functional properties of meat analogues. In this presentation, we will discuss how the properties of TVP are related to these various characteristics. The knowledge on water absorption and release can be used to improve the juiciness of meat analogues, and can help to optimise the production processes of TVP.

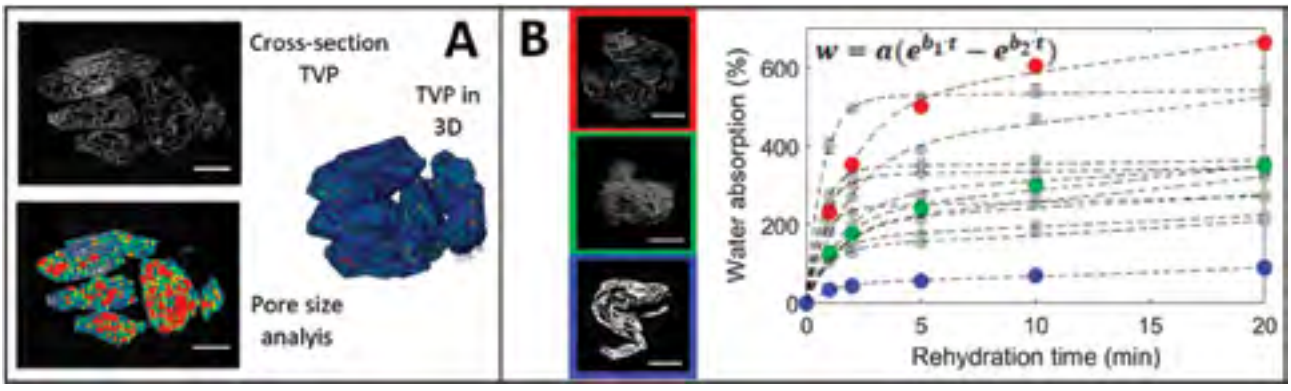

Figure 1. (A) X-ray computed tomography images of TVP: cross-section of TVP and example visualisations of pore size analysis in 2D and 3D. (B) Water absorption as function of rehydration time, where three TVP samples were highlighted and visualized in the form of 2D image slices.

Acknowledgements: Topsector Agri & Food, grant number LWV-20.078

Hierarchical structures of plant-based meat analogs across multiple length scales

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ABSTRACT

Current unsustainable meat consumption brings concerns on health, ethic and animal welfare. Many meat consumers turn to (partly) plant-based diets. To facilitate the transition, the demand for a product which has an accurate reproduction of meat-like structure, texture and mouthfeel is pressing. Plant-based meat analogs (PBMAs) hold an important share of the meat substitutes market, due to such close reproduction. However, the knowledge of mechanisms of the meat-like structure formation and systematic characterization across multiple length scales, especially down to nano-scale are limited. High Moisture Extrusion Cooking (HMEC) in an extruder is one of the methods to produce PBMAs. The key to reproduce meat-like structures are the plastification and texturization which take place in a cooling die attached to the end of the extruder. However, the "black-box" characteristics of the extrusion process make understanding this process difficult. Therefore, we have performed *in situ* Small-angle Neutron Scattering with a customized neutron-transparent cooling die (**Fig.1**) to shed light on the plastification and texturization mechanisms throughout the entire cooling process of extrusion. Contrast variation via solvent deuteration was applied to determine the contribution of the different components. Hypotheses were proposed as the mechanisms of the fiber formation. Moreover, a systematic characterization across multiple length scales was performed. The orientation of the fibrous structure according to flow profile in the cooling process on nano-scale was mapped by scanning Small-angle X-ray Scattering; the texture properties on micro-scale were revealed by combining X-ray Tomography and rheology; Charaterization on millimeter-scale by texture analysis was performed. Our results contribute to a detailed insight into PBMA structuring mechanisms, and a systematic characterization on PBMA, and thereby help pave the way towards a more sustainable nutrition.

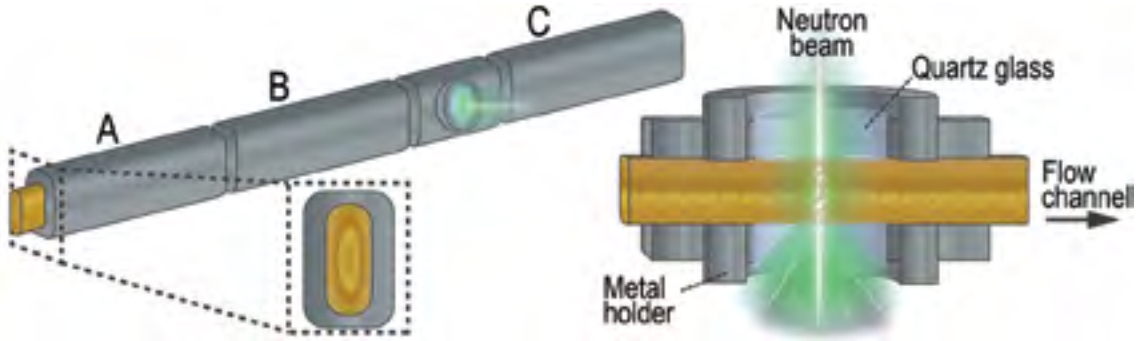

Figure 1. Configuration of the cooling die with standard cooling elements A – C and the custom-made element with neutron-transparent quartz glass windows. The window element is shown in more detail in the right part of the image. The brown rectangle represents the PBMA extrudate with characteristic flow-induced structures.

Acknowledgements: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska–Curie grant agreement No. 847439.

Revealing the efficiency of aroma molecules as co-surfactants in surface-emerging processes

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ABSTRACT

The ability to guide fast interfacial processes in multi-component non-equilibrium systems is a significant fundamental and practical task. Presented research demonstrates the potential of unique functional properties of poorly water-soluble aroma molecules, i.e. high dynamic surface activity in a millisecond range, as well as the ability to desorb from the surface into the gas phase at times of the order of seconds, in the optimization the dynamic processes of surface formation.

Insights into the interfacial behavior of volatile amphiphiles, as well as of their mixtures with conventional surfactants are provided by dynamic and static tensiometry studies. A novel approach based on pending drop sensing tensiometry proved to be a sensitive method in assessing the concentration of volatiles in the vapors above complex systems (Figure 1).

Application examples include fabrication of emulsions, miniemulsion polymerization, wetting and spreading phenomena, as well as assessment of aroma release form complex formulations. In particular, the rheological characteristics and release of aroma molecules from thixotropic oil-in-water emulsions correlate with the preparation procedure, confirming incorporation of aroma molecules into the interfacial layer.

Reported findings are envisaged to improve the understanding of the role of aroma molecules in fabrication of food colloids.

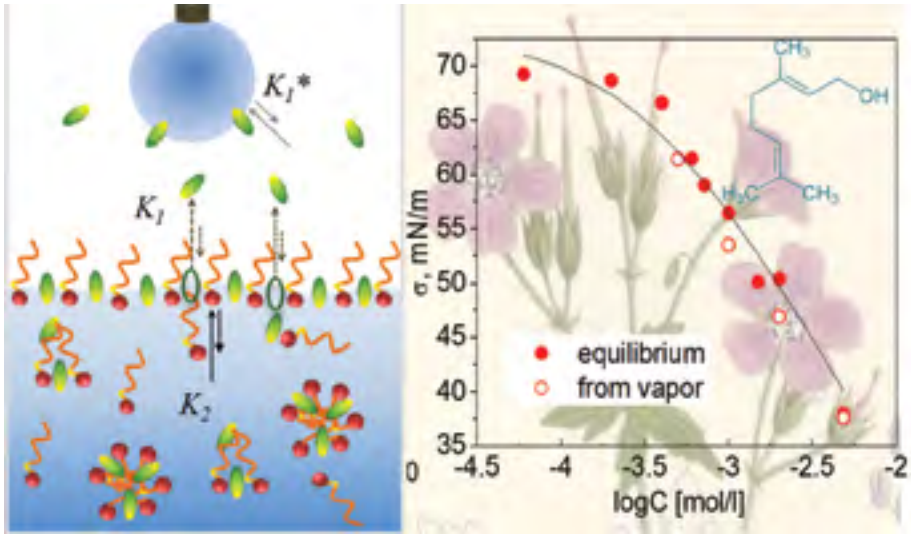

Figure 1. Left: Schematic of the experiments based on the tensiometric sensing of the volatile surfactants. Right: Comparison of the equilibrium surface tension isotherm, resulting from the adsorption of a volatile from bulk solutions, with that resulting from its adsorption on a surface of a water drop from the head-space volume above solutions with indicated concentration

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SANS and SAXS: a Love Story to Unravel Nanostructural Evolution of Soy Proteins and Polysaccharides during High Moisture Extrusion

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ABSTRACT

Plant-based meat alternatives are seeing considerable interest due to their potential to reduce environmental degradation and enhance population health. The food industry therefore seeks routes to provide the consumer with whole-cut plant-based products that closely resemble meat products. High-moisture extrusion of plant proteins enables the industrial manufacturing of meat-like products with highly hierarchical structural organization of fibres. The major bottleneck in serving the growing market for these products is a lack of insight into how multiscale structures, from nano- to macro-scale, evolve during shear processing. Furthermore, it remains an open question of how two biopolymers, one being a plant protein and the other being a polysaccharide, contribute to the anisotropic structure formation during high-moisture extrusion. In this study, we show how the complimentary use of small-angle neutron scattering (SANS) and small-angle X-ray scattering (SAXS) can add clarity to these matters. Since neutrons and X-rays interact differently with matter, SANS and SAXS themselves represent different contrasts. Thus, with higher sensitivity of neutrons to proteins, and X-rays to polysaccharides, we can shed light on the nanostructural evolution of both during shear processing. We demonstrate that the size of protein aggregates that probably constitute the building blocks of the protein fibrils seems to remain roughly the same at the end of the extruder barrel section and along the entire cooling die. Alignment of protein fibrils is already present in the extruder section and develops further along the cooling die, while for polysaccharides, the alignment extent decreases in the cooling die. Combining small-angle scattering techniques with additional measurement methods, such as microscopy and magnetic resonance imaging, allows us to assess anisotropic structure formation and evolution on multiple length scales.

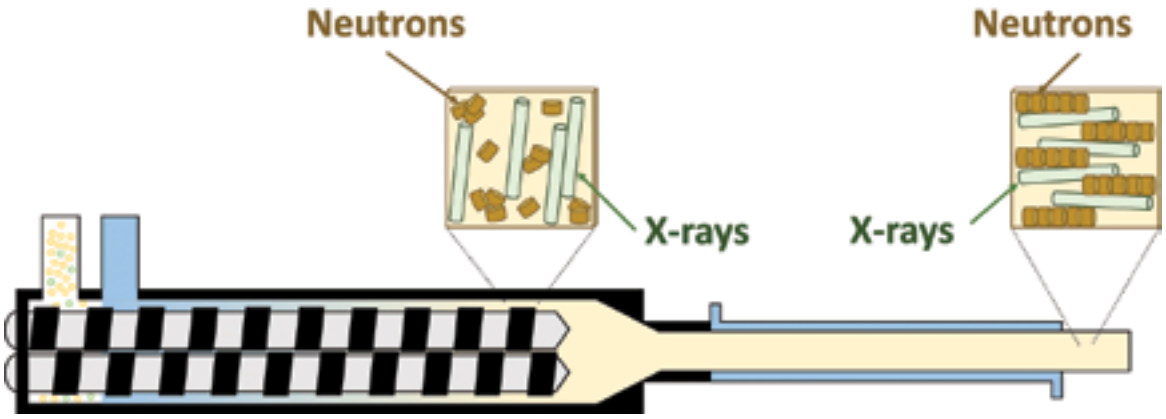

Figure 1. Schematic diagram of high-moisture extrusion. Higher sensitivity of neutrons to proteins (gold disks) and X-rays to polysaccharides (green cylinders) enables the study of the nanostructural evolution of both during processing.

Acknowledgements: This work is part of the project "Measurement and Modelling of Multiscale Processed Protein Products (MP3)" (with project number 18744) of the research programme OPT TTW which is financed by the Dutch Research Council (NWO) as well as contributions from consortium partners Unilever, Cargill, DSM, FrieslandCampina and Wageningen Food and Biobased Research. Experiments at the ISIS Neutron and Muon Source were supported by a beam time allocation RB2269101.

08. EMULSIONS, FOAMS, GELS FROM CLASSICAL APPROACHES TO NOVEL SYSTEMS I

Fabrication of electrospun short fiber-based aerogels as template for preparing oleogels

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ABSTRACT

This work proposed an innovative and facile approach to construct aerogel-templated oleogels (ATO). In the first phase, the freeze-dried gelatin aerogel templates were developed from uniformly dispersed electrospun short fibers (GF), which were further immersed in camellia oil within 5 min to form ATO. Compared with traditional gelatin hydrogel-based (GH) aerogels, GF aerogel templates presented highly porous microstructures, thermal stabilities, and significant changes on infrared spectrum and secondary structure. In compression tests, GH aerogels possessed strong resistance to stress while GF aerogels exhibited surprising resilient abilities. In addition, the oil adsorption capacity (OAC) and oil holding capacity (OHC) of GF aerogel templates considerably reached 125.31 g/g and 79.40%, respectively. In addition, the oleogels presented outstanding rheological properties and *in vitro* digestibility. In the second phase of work, aerogel templates were constructed from electrospun gelatin/gluten composite nanofibers, and then heated for 2 or 20 h (F88, F88-2, and F88-20, respectively). The templates with a high degree of thermal crosslinking owned a good hydrophobicity, and the the obtained oleogels showed a controlled release of free fatty acids during digestion. In summary, this work suggested that ATO fabricated from electrospun short fibers owned a more desired physical structure and oil-related properties, and the thermal modification on protein aerogel templates would be beneficial for fabricating a more stable oleogel structure with more steady release behaviors during *in vitro* digestion.

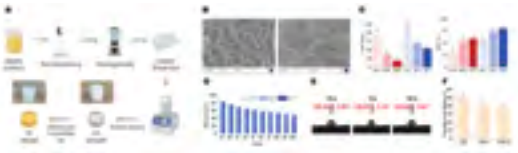

Figure 1. (A) Schematic procedure of preparing GF oleogels. (B) Micrographs of GH and GF aerogels. (C) OAC and OHC of the samples. (D) Fatigue tests of the GF aerogel templates. (E) Water contact angle of the F88-20 aerogels. (F) Free fatty acid release of the oleogels. Different letters in the same graph indicate significant differences ($P < 0.05$).

Acknowledgements: The research was supported by the National Natural Science Foundation of China (Grant No. 32272463).

Protein-Polyphenol Networks in High Internal Phase Emulsions: Mimicking the temperature-dependent rheology of adipose tissue

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ABSTRACT

Animal adipose tissue, which is composed of adipocytes in an extracellular matrix (ECM), is challenging to replicate or replace, due to its distinct rheological properties and microstructure. To recreate the temperature-dependent properties, a droplet-like fat phase and a temperature-sensitive network, similar to the ECM, are necessary. Previous research attempted to replicate adipose tissue using solid fats, hydrogels or oleo-gels, but was, generally, unsuccessful in obtaining similarly unique temperature-dependent properties. We hypothesise that by incorporating a secondary temperature-dependent network through protein-polyphenol interactions in a high internal phase emulsion (HIPE) it is possible to mimic the properties of adipose tissue, even when using liquid oils.

We studied protein-stabilised oil-in-water emulsions near their maximum droplet packing fraction (φ), while varying their solid fat content (SFC). In addition, we introduced protein-polyphenol interactions, resulting in intra- and inter-droplet cross-linking and the formation of a secondary network. We followed the rheological behaviour, texture, and microstructure of the emulsions during temperature cycling, and compared the changes with those of adipose tissue.

Emulsion droplet jamming led to the formation of a primary network, causing an increase in material stiffness (G') with φ and SFC. HIPEs consisting of liquid droplets but without secondary network were temperature independent, above the melting point of the lipid phase. Emulsions containing solid fat softened reversible. Introducing the secondary, non-covalent network, increased G' further, to a value similar to adipose tissue, even in emulsions with liquid droplets. Moreover, G' decreased 3-4 orders of magnitude with increasing temperature, in liquid and solid fat HIPEs, due to H-bridge breakdown. HIPEs with polyphenol-protein interactions maintained a predominantly elastic behaviour at elevated temperatures, for solid and liquid fat emulsions, alike. By controlling φ, SFC and protein/polyphenol ratio, a variety of temperature-dependent rheological behaviours can be obtained, which were in agreement with behaviour of adipose tissue.

Tuning the properties of ethanol pre-treated whey nanoparticles for emulsion stabilization: effect on the in vitro lipid digestion

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ABSTRACT

This study explores the potential of ethanol pre-treated whey protein nanoparticles as a new alternative candidate for stabilizing emulsions, highlighting their unique properties and emphasizing their potential benefits for improving food functionality and human health. To achieve this, nanoparticles with controlled size, and physicochemical characteristics were prepared under different environmental conditions (pH and ionic strength). The prepared nanoparticles were assessed for their ability to act as emulsion stabilizers, while the produced emulsions were evaluated for their impact on *in vitro* lipid digestion.

Nanoparticles were formed at varying ethanol concentrations (30–70% w/w) and low protein concentration (1.0–2.0% w/w) by regulating pH and ionic strength. The ethanol was subsequently removed through a two-step process involving rotary evaporation and freeze drying. The ethanol-free particles were utilized for the preparation of oil-in-water (o/w) emulsions which were then studied in terms of their stability and impact on the *in vitro* lipid digestion. Laser diffraction analysis and confocal laser scanning microscopy were employed to characterize the created nanoparticles and emulsions, while scanning electron microscopy was utilized for the morphological characterization of the particles.

The findings of this study highlight the crucial role of controlled environmental conditions in obtaining nanoparticles of specific size and properties after ethanol removal. The o/w emulsions prepared with whey protein nanoparticles showed remarkable stability against coalescence during a month of storage, likely attributed to the effective adsorption of particles at the oil-water interface. Finally, the particle-stabilized emulsions exhibited enhanced resistance to lipid digestion when compared to conventional WPI-prepared emulsions. These results show the potential of ethanol-denatured nanoparticles as functional ingredients with potential benefits for enhanced stability, leading to new opportunities for the development of food products with improved characteristics.

Surfactant-free microemulsions for the synthesis of antioxidants for food applications

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ABSTRACT

Weak self-assembly systems consisted by a nonpolar hydrocarbon, an alcohol and water can form macroscopically homogeneous liquid media with distinct microenvironments of varying polarity. These ternary systems are very similar to classic water in oil microemulsions although they lack any amphiphilic surfactant. They were thus, initially called "surfactantless" or "detergentless" microemulsions. One of the main application fields that these systems cover is the one of biocatalysis in non-conventional media, a pillar of industrial biotechnology [1].

In this work, the ability of surfactant-free microemulsions to serve as biocatalytic reactors is examined. For this purpose, surfactant-free microemulsions were prepared using hexane, water and a short chain alcohol such as 1-propanol or t-butanol and lipases such as *C. antarctica* and *M. miehei* were incorporated. The systems were studied structurally with various techniques (such as EPR, Fluorescence spectroscopy, energy transfer, conductivity) and the lipases catalytic activity was monitored in relation to the system's structure [2]. Moreover, Hydroxy(propylmethyl) cellulose (HPMC) microemulsion-based organogels (MBGs) formulated with various surfactant-free microemulsions were used as a matrix for enzyme immobilization. These lipase-containing MBGs prove to be a novel solid-phase catalyst for use, under mild conditions, in non-polar solvents as well as in solvent free systems [3].

Finally, the surfactant-free microemulsions and the related organogels were used for the synthesis of phenolic compounds that can serve as antioxidants to be applied in various food matrices.

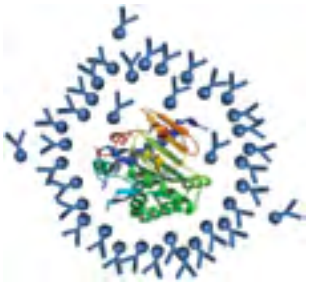

Figure 1. Model arrangement of the protein molecule within a water pool, with the propanol molecules forming the interface between hexane and water.

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Emulsions for Food Applications Stabilised by Mixtures of Lecithin, Glycerine Monooleate (GMO), and Na Oleate

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ABSTRACT

Oil-in-water emulsions, able to deliver valuable nutrients, e.g. omega-3 fatty acids, are interesting components in food science, but typically the formulation of colloidally stable emulsions of well-defined size can be a major challenge, and this problem may even be enhanced when using food grade oils, such triacylglycerides. In this work we studied mixtures of three food compatible amphiphiles, soja lecithin, glycerine monooleate (GMO), and sodium oleate as emulsion stabilisers. The first two have a tendency for forming bilayers in aqueous solution, while sodium oleate forms micelles at high pH and bilayers in form of vesicles at more neutral pH. In our experiments we first studied size and structure of the aggregates of the ternary amphiphile mixtures formed in aqueous solution. In a next step we determined the interfacial tension (IFT) of these mixtures against paraffine oil and caprylic/capric triglyceride as a function of the composition of the mixtures. Here marked synergistic effects in reducing the IFT were observed by appropriately mixing the different components. Emulsification experiments by sonication and vortexing were done around the minimum IFT values and the formed emulsions and nanoemulsions were characterised with respect to their size and ageing properties. The size of the formed droplets was in the range of 150 nm to 10 µm, as determined by static and dynamic light scattering experiments and laser light diffraction. In general, the droplet sizes are the smaller the lower the IFT and also the colloidal stability of the droplets formed correlates well with the IFT values. In summary, this means that droplet size and stability of these food-grade emulsions can be tailored by appropriately choosing the composition of the amphiphilic mixture.

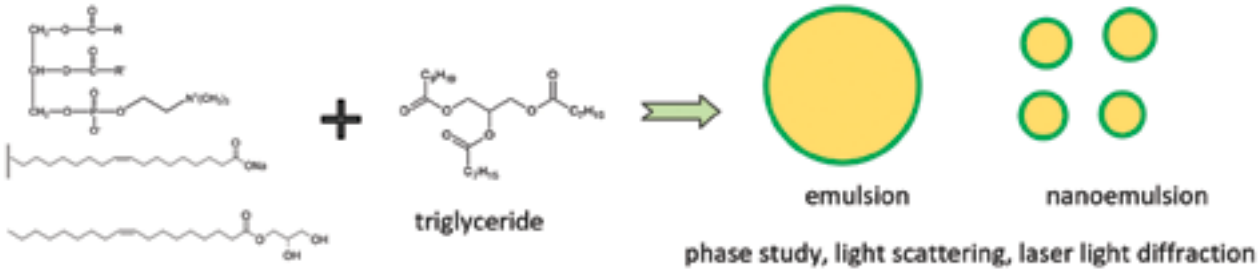

Figure 1. Scheme of the formation and characterisation of triglyceride (nano)emulsions with Na oleate, lecithin, and monoolein as stabilisers.

Thermogelation of pea protein stabilized nanoemulsions co-formulated with methyl cellulose for plant-based food analogues

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ABSTRACT

We investigate the functional properties of pea protein isolate (PPI) to stabilize nanoemulsions and its role in thermogelation. We use high-pressure homogenization to form peanut oil droplets which are stabilized by a commercial PPI. This leads to kinetically stabilized emulsions with sub micrometer sized droplet diameters, also known as nanoemulsions. A successive increase in temperature induces denaturation of the adsorbed proteins and leads to gelation of the nanoemulsion.

We co-formulate methyl cellulose as a second gelation agent, which can form a network on its own [1]. We show that the thermogelation of the co-formulated system is synergistic, and the gelation mechanism can be tuned from homogeneous gelation to yielding more heterogeneous structures. We perform detailed rheological measurements alongside fluorescent confocal microscopy. This allows us to relate the microscopic structure formation of each component with the gelation process of the nanoemulsion (see Fig. 1).

This demonstrates the potential of PPI stabilized nanoemulsions to be used in thermo-mechanical processing for plant-based foods beyond milk analogues and fortification, but also as a precursor for denser structures such as meat analogues. Furthermore, the oil droplets of the nanoemulsion can be decorated with hydrophobic nutrients such as Vitamins A, D, E, and K, carotenoids, and polyunsaturated fatty acids to create healthy plant-based foods.

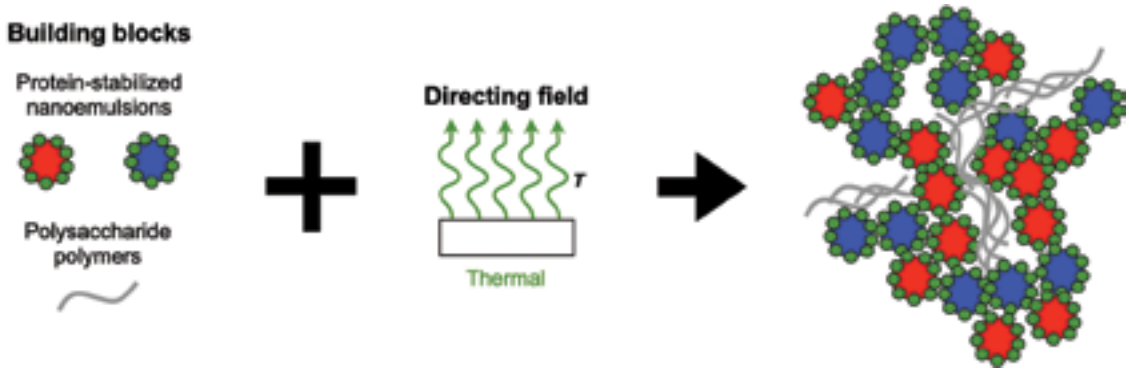

Figure 1. Illustration of the gelation process

References: [1] Liang-Hsun Chen and Patrick S. Doyle, Adv. Mater. 2021 (33), https://doi.org/10.1002/adma.202008618

Acknowledgements: This project is funded by the Postdoc.Mobility program of the Swiss national science foundation.

09. SURFACTANTS, LIPIDS, MACROMOLECULES, PARTICLES ADSORPTION, INTERACTIONS AND SELF-ASSEMBLY I

Current view on the adsorption dynamics of bovine serum albumin at water/air interface

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ABSTRACT

An important aspect of the scientific area of proteins at fluid interfaces is the dynamics of adsorption from the bulk of a solution to its surface and the establishment of a durable interfacial layer. Many experimental studies have led to a clear qualitative picture of the adsorption process and efforts have been put into quantifying it by various theoretical models [1-4]. Here we deal with this long-standing problem and present a current position. We investigated adsorption layers of the globular protein bovine serum albumin (BSA) at the water/air interface by tensiometry, dilational rheometry and ellipsometry. A comprehensive set of experimental data on kinetic and (quasi-)equilibrium dependences of the surface pressure Π, the surface excess Γ and the dilational elasticity E for a wide range of BSA concentrations c was generated. These data were theoretically analyzed by thermodynamic and kinetic models [3,4]. In the latter case, we employed a new approach, assuming the adsorption activity coefficient b in the adsorption isotherm $b(t)c = f(\Gamma)$ as time-dependent [3]. The value of b increases with time t up to the limiting value b_1 (maximum surface activity at steady state). This dependence $b(t)$ was introduced to account for contributions of various kinetic processes within the protein adsorption layer due to interactions of different physicochemical nature, *e.g.*, interactions of protein globules with the interface (conformational transitions) as well as in-plane intermolecular interactions between adsorbed globules (2-D aggregation and network formation). The effective interplay of these interfacial rearrangement processes is presumably weakly dependent on the rate of diffusion transport towards the interface, but exhibits a certain time evolution (quantified by a kinetic constant) towards a steady state observed after sufficiently long adsorption times. Hence, we consider a mixed *diffusion-surface rearrangement* adsorption mechanism. The proposed kinetics model operates with a fixed diffusion coefficient and describes very well the experimental data.

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Acknowledgements: Partial financial support from NCN project SONATA-BIS No. 2020/38/E/ST8/00173 is acknowledged with gratitude.

Isolating the Interface of an Emulsion using X-Ray Scattering and Tensiometry to Understand Protein-Modulated Alkylglyceride Crystallisation

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ABSTRACT

Dairy proteins and mono- and diglycerides (MDG) are often used in unison to tailor the properties of dairy-based emulsions. However, there are significant gaps in our understanding of how proteins affect lipid crystallisation at the oil-water interface. We have used a unique combination of interfacially-sensitive techniques to elucidate the impact of dairy proteins on interfacial MDG crystal formation.

The formation temperature of interfacial MDG crystals was assessed through interfacial tension studies via drop shape analysis. Small and Wide-Angle X-ray Scattering measurements were performed on isolated oil-water interfaces, allowing for in-situ interrogation of MDG crystal structure and concentration at and near the interface.

Dairy proteins are seen to reduce the temperature at which MDG crystals form at the oil-water interface. The displacement of proteins upon interfacial crystal formation was also clearly observed in interfacial tension measurements. For the first time, lipid crystals formed at the oil-water interface have been characterised using X-ray scattering. All scattering studies showed no change to the MDG crystal structures at the oil-water interface in the presence of adsorbed proteins. The results demonstrate that informed selection of emulsifier components is critical to controlling interfacial crystallisation with concomitant impact on emulsion stability.

The effect of pH on enzyme catalyzed lipolysis at the oil/water interface

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ABSTRACT

Triglycerides are a vital source of nutrients and energy. However, they are not adsorbed intact in the digestive tract. Lipases and pH operate at the oil-water interface and hydrolyze them into more hydrophilic and amphiphilic products, including fatty acids and monoglycerides. Their effect on the structure of the oil-water interface, which is key for digestion kinetics and nutrient transfer, is not yet fully understood. They may generate new oil-water interfaces that assure sufficient progress of digestion.

This contribution reports on the interfacial modification during pH- and enzyme-triggered hydrolysis of triolein in the presence of water. Spinning drop tensiometry, imaging ellipsometry, and microfocus small angle X-ray scattering (SAXS) demonstrate the formation of nanostructured interfacial layers between oil and water. The simultaneous analysis of colloidal structure formation in the oil and water phases with SAXS and dynamic light scattering showed the spontaneous formation of highly monodisperse water-in-oil emulsions inside the triolein phase, containing lipase. Techniques such as Karl Fischer titration and Bradford's assay confirm the water transfer into the triolein. Importantly, acid-base titration shows the lipase retains its ability to break down lipids once in the oil phase.

The findings offer valuable insights into pH and lipase-catalyzed triglyceride hydrolysis. We've explored various pH and ionic strength conditions to understand this process better. Hydrolysis time and pH were found to have symbiotic effects, gradually tuning the oil-based environment to more hydrophilic structures with high internal surface area. This knowledge contributes to the fundamental colloidal understanding of the lipid digestion process that is vital for survival and nutrient supply. The colloidal structure formation is linked to its function as carrier for lipases and nutrients.

10. SURFACTANTS, LIPIDS, MACROMOLECULES, PARTICLES ADSORPTION, INTERACTIONS AND SELF-ASSEMBLY II

On the structural changes of edible oils by using green biobased tools to control the functional properties

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ABSTRACT

Industry needs new natural ingredients – there is a lack of knowledge of the fundamentals of controlling lipolysis in complex matrices. Based on neutron and x-ray data we will show the nature of the oil/water-interphase and how the processes that can occur during lipolysis can change the structure and composition in the interfacial layer. We will discuss how triglycerides can orient at the interface and lead to uptake of water [1]. Neutron reflectivity shows that the internal structure is very complex after lipolysis. Modelling suggests a highly disorganised, stratified structure that depends on the pH. Based on these experiments we will discuss the modification of edible oils from plant raw materials. Such information can be used to predict stability of food formulations and can serve as a tool to design and build up new and more complex matrices. We show that a new thick creamy emulsion based on oat oil can be created without additives with green biobased tools. X-ray data show that this is due to the structural change in the oil. The conditions of the dispersing solution can be used to tune the final emulsion properties. The study is part of an ongoing project aimed at obtaining more sustainably produced food ingredients that needs less additives and energy. In the long term new healthy products can be developed as e.g., carriers for bioactive food ingredients.

Figure 1. A. ATR-FTIR spectra shows that the triolein (red) at the interface is digested into oleic acid and oleate at pH7 (blue). B. A new thick creamy emulsion based on cereal oil can be created using green biobased tools. C. SAXS data reveals a range of structure depending on the processing conditions

References: [1] B. A. Humphreys, J. Campos-Terán, T. Arnold, L. Baunsgaard, J. Vind, C. Dicko, T. Nylander, The influence of pH on the lipase digestion of nanosized triolein, diolein and monoolein films. *Front. Soft Matter* 2**022**, 2, 929104.

Acknowledgements: We are grateful for the financial support from Swedish Research Council (2018–05013) as well as The Swedish Agency for Economic and Regional Growth (20307448) through the European Union Regional Fund and the Skane Region. The valuable discussions and input from José Campos-Terán, Thomas Arnold, Lone Baunsgaard,

Jesper Vind, Max Skoda, Philipp Gutfreund and Cedric Dicko are gratefully acknowledged.

Production of pea protein microgels and evaluation of their compression behavior at the air/water interface

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ABSTRACT

Protein microgels have been extensively investigated as potential stabilizers of food grade Pickering emulsions. In order to be successfully applied, it is important to know microgels' characteristics and, more importantly, to understand their behavior upon adsorption at interfaces. Therefore, the aim of this work was to produce and characterize pea protein microgels (PPM) as well as describe their compression behavior at the interface air/water. The microgels were produced by thermal treatment, followed by ultrasonication to reduce the aggregates´ size. Then the microgels were characterized by mean size, zeta potential, morphology and surface hydrophobicity. The compression behavior of pea protein microgels was evaluated by creating an artificial interface in a Langmuir-Blodgett trough. For this purpose, the microgels dispersion was carefully placed on the top of the subphase (water), and the barriers start the compression (5 mm/min), after an equilibration time of 30 min. The results showed that PPM had mean particle size of 237 ± 8 nm and - 21.8 ± 0.7 mV of zeta potential. The size distribution curves indicated the presence of aggregates of larger sizes, which was confirmed by transmission electron micrography. Microgels presented higher surface hydrophobicity compared to native pea protein, with contact angles of 53.2 ± 1.1° and 36.0 ± 3.4°, respectively. The increased hydrophobicity is justified by the exposure of hydrophobic sites of protein molecules during the thermal treatment applied to produce the microgels. The compression isotherms obtained for PPM indicated that, after adsorption, conformational changes occurred in microgels at the interface, probably caused by a balance between surface activity and microgel internal elasticity. These microgel monolayers are compressible to an extend that depends on their internal elasticity and adsorption strength. In conclusion, the produced PPM presented an adsorption behavior similar to that of soft particles, being a promising material for Pickering emulsion stabilization.

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Self-assembly of oat proteins into various colloidal states as function of the NaCl concentration and pH

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ABSTRACT

Oats are increasingly used in a range of liquid and semi-solid foods. Insights into the behavior of native oat proteins in aqueous media are crucially important to understand their functionality, but are sorely lacking. Here, the impact of varying NaCl concentration and pH on the colloidal state of native oat proteins was systematically studied. Non heat-treated oat groats were used as raw material to produce oat protein isolates (OPI). First, a centrifugation step at high centrifugal force (50,000 g – 4h) was carried out to remove partly aggregated material from an OPI dispersion at pH 10.0 and thus to obtain a solution containing native, non-aggregated oat globulins only. Upon addition of varying concentrations of NaCl to such a native OPI solution at pH 10.0, oat proteins self-assembled into different colloidal states. Most notably, at <50 mM NaCl, oat proteins formed protein aggregates with a fractal dimension of 1.8, while at 50-300 mM NaCl, oat proteins microphase-separated to form concentrated protein droplets of ≥ 1 µm. To allow assessing the impact of pH systematically, titration experiments were performed to establish the relation between pH and protein charge density (α). Upon changing the charge density of a native OPI solution, protein microphase separation was found to occur in the region α = -155 (pH 8.2) to α = -118 (pH 7.1). At lower charge densities (and thus pH values), this phenomenon was no longer observed, but protein aggregation occurred, and pronouncedly so at the protein iso-ionic point (α = 0, pH 5.0). In conclusion, oat proteins self-assemble into different types of colloidal structures at varying NaCl concentration and pH. This could have important implications for the properties of oat proteins in a variety of foods and should be investigated further.

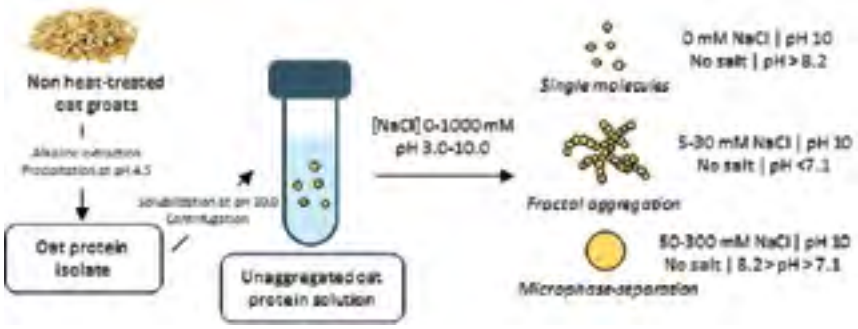

Figure 1. Graphical abstract

Acknowledgements: A.G.B. Wouters acknowledges FWO Vlaanderen (Fonds Wetenschappelijk Onderzoek) for funding for a research stay at Université Le Mans (ref. V432222N).

Polyphenol release aggregation and its sensory consequences

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ABSTRACT

Descriptive sensory analysis was used to characterize the flavour changes of peanuts during boiling. The attributes investigated were rawness, astringency, and bitterness. Samples with skin and without skin were compared. A descriptive panel (n=25) evaluated 12 coded samples served in random order using a scale of 7 points. The average results showed that the rawness decayed during the cooking, and it took about 60 minutes to obtain a neutral character. Astringency appears to be the primary attribute contributing to the complex rawness attribute of the peanut sauce. Bitterness appeared to be less important for the perceived rawness. The sensory properties are created by the release of polyphenols from the solid matrix during boiling. However, further processing leads to aggregation, making the sensation gradually milder.

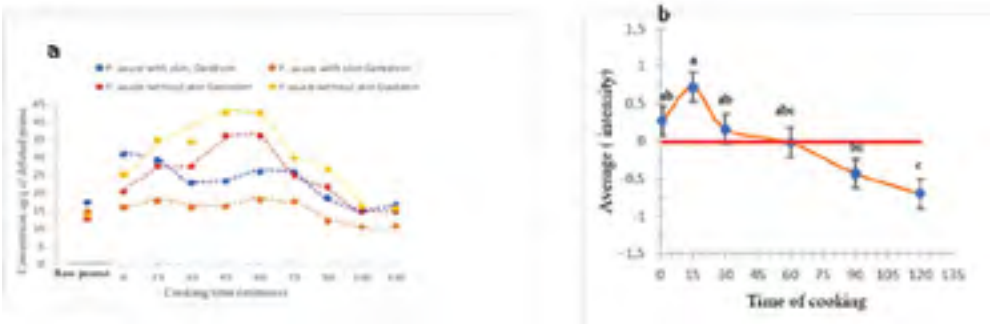

Figure 1. Profile of phenols (Figure 1(a)) during the cooking time and centred and normalized intensities of the sensory attributes Astringency, and (b) of peanut sauce made from peanuts without skin as a function of boiling time.

Acknowledgements: The studies are supported by the Swedish International Development Agency (SIDA) in a collaborative project between Eduardo Mondlane University (Mozambique) and Lund University (Sweden).

Probing the particle formation and aggregation behaviour of gliadin in aqueous ethanol with ultra-small- and small-angle X-ray scattering

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ABSTRACT

Colloidal gliadin particles show promise for use as interface stabilizers and for the encapsulation and delivery of bioactive molecules in food systems. Gliadin particles can be produced with a simple liquid antisolvent precipitation (LAS) technique. The dynamics of the protein interactions and conformational changes due to changes in solvent quality during LAS have yet to be fully unravelled, despite the fact that these are important for particle functionality. In this study, ultra-small- and small-angle x-ray scattering (USAXS/SAXS) were used to investigate the assembly of gliadin proteins into particles and aggregates throughout LAS. The unified fit model was used to analyze each structural level (confined to different scattering vector q-regions). At low ethanol concentrations (12–20 v/v%), two hierarchical structural levels were identified. The high q-region ($q > 3 \times 10^{-2}$ $Å^{-1}$) suggested that 2-D primary basic units (PBUs) were formed (R_g = 4–8 nm, $2 < P < 2.5$), while for the low q region ($q < 3 \times 10^{-2}$ $Å^{-1}$), rough spherical nanoparticles were observed (R_g = 200–300 nm, $3 < P < 4$). Gliadin particles at these low ethanol concentrations measured by dynamic light scattering were monodisperse and had similar mean diameters, providing evidence that the larger structures measured by USAXS/SAXS were, in fact, gliadin particles. Only one structural level was observed for the concentrations of aqueous ethanol at which gliadin is most soluble (50–70 v/v%) which had similar size and shape to the PBUs detected for the low ethanol systems, indicating that gliadin does not form larger particles or aggregates at these conditions. Furthermore, analysis with Fourier-transform infrared spectroscopy indicated that gliadin underwent secondary structural changes, with an increase in intermolecular β-sheets during particle formation. This work shows that USAXS/SAXS can be used to elucidate the self-assembly of gliadin molecules at multiple length scales.

Acknowledgements: This research used resources of the Advanced Photon Source, a U.S. Department of Energy (DOE) Office of Science User Facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357. The authors thank the Government of Ontario (Ministry of Research and Innovation, Early Researcher Awards program) and the Natural Sciences and Engineering Research Council of Canada (NSERC Discovery program) for funding this project.

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11. FROM NANO TO MACRO INTERFACIAL STRUCTURE VS COLLOIDAL STABILITY AND PROPERTIES

Liquid-liquid phase separation in heteroprotein systems: recent advances

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ABSTRACT

Liquid–liquid phase separation (LLPS) has emerged as a new paradigm in the fields of soft matter, colloid chemistry, food science and cell biology. Research in this area constitutes a fine example where physics and biology intertwine harmoniously. LLPS is a dynamic assembly process that leads, *in vitro* solution as well as *in vivo*, to the formation of micrometer-sized droplets, which are referred as biomolecular condensates, membrane less organelles, liquid droplets or complex coacervates, depending on the scientific community concerned [1,2]. In this presentation, I focus on LLPS that occurs in binary cationic and anionic protein mixtures (heteroprotein systems, HPCC). I briefly review aspects that are of particular interest: formation dynamics; main driving forces; physical and chemical properties; functions and applications. Throughout studied binary protein systems, the route to complex coacervation involves the formation of intermediate hetero-oligomers specific for each binary system. Dimers, tetramers, or pentamers were identified (Fig. 1). While the mechanism behind the association of these primary units into building blocks and their growth to form complex coacervates remain elusive, I will present and discuss the main relevant structural and physicochemical parameters for HPCC. Finally, the challenges and future research directions in particular how HPCC can be explored in the food sector for the encapsulation and protection of bioactives or to modify the viscosity of the food matrices will be discussed.

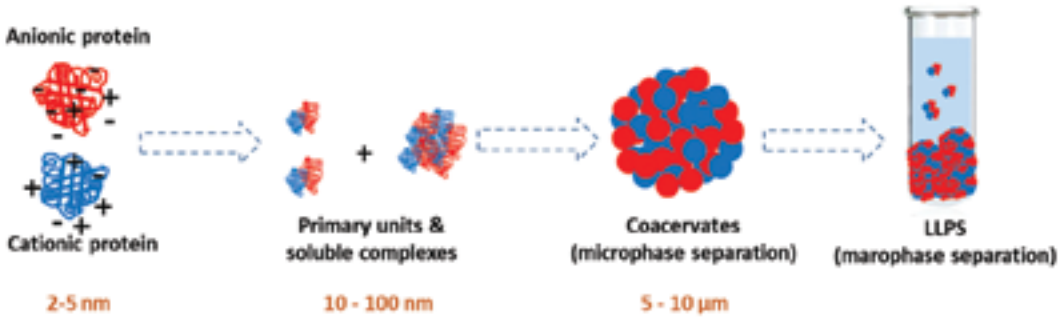

Figure 1. Associative liquid-liquid phase separation process in heteroprotein systems

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Interfacial rheological properties of pepsin-hydrolyzed lentil protein isolate at oil-water interfaces

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ABSTRACT

Lentil protein isolate (LPI) was investigated for its potential as a plant protein-based emulsifier. LPI consists mainly of globulins with high molecular weights which are relatively slow to adsorb at an oil-water interface. Smaller proteins, such as whey protein, can adsorb much faster at the interface, quickly forming a viscoelastic film that slows down the rate of droplet recoalescence, leading to smaller droplets. To increase the rate of adsorption, LPI was enzymatically hydrolyzed by pepsin at 1.5% and 4.5% degree of hydrolysis (DH), to obtain small peptides. We studied the behavior of these peptides at the O-W interface in comparison to whey protein isolate (WPI) and native lentil protein isolate (LPI). These proteins were investigated in large amplitude oscillatory shear (LAOS) and large amplitude oscillatory dilatation (LAOD) to investigate the interfacial behavior and relate this to the protein characteristics and emulsion formation. The 1.5% and 4.5%DH LPI showed high surface hydrophobicity, and consisted mainly of low molecular weight peptides, which contributed to faster adsorption kinetics and consequently covered the interface faster than LPI. Nonetheless, the emulsion prepared with both hydrolyzed LPI samples was not stable due to the droplet flocculation during emulsion preparation. Upon the addition of SDS to break flocs, the droplet size formed by both hydrolyzed LPI was indeed smaller than LPI stabilized droplets, and close to the droplet size formed by WPI. For the interfacial properties, both hydrolyzed LPI formed brittle and less stretchable interfaces compared to LPI, and in-plane interactions between adjacent protein molecules were clearly weaker than in WPI-stabilized interfaces.

Acknowledgements: This study was supported by funding for a PhD scholarship from Royal Thai Government Scholarship

Pea protein's interfacial behaviour as affected by high-pressure homogenization treatments: an in-depth study with dilatational rheology characterization

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ABSTRACT

In the dynamic landscape of modern food science, the exploration of plant-based alternatives, particularly pea proteins, as ingredients for plant-based products has gained significant attention. Innovative technologies like high-pressure homogenization (HPH) have been employed to enhance the techno-functional properties of these proteins, consequently shifting the focus towards understanding their impact on protein structure and matrix stability. Hence, this study investigated the effects of HPH treatments at different pressures intensities (60 and 100 MPa, 5 cycles) on the interfacial and emulsifying properties of pea proteins. A comprehensive analysis of the interfacial layer using pendant drop analysis, examining changes in interfacial tension and dilatational rheology during adsorption and desorption at the o/w interface were carried out. Model oil-in-water emulsions (20% w/w) with native and HPH-treated pea proteins were formulated, and the droplet size and physical stability over time with Turbiscan were monitored. Additionally, ζ-potential measurements were conducted on both protein dispersions and emulsions. Findings revealed that HPH treatments diminish the interfacial activity of pea proteins, impacting their dilatational viscoelasticity at varying frequencies. ζ-potential analysis suggested that HPH induced the formation of smaller peptides and/or conformational changes in protein structure, confirmed also by the decrease of both the penetration and rearrangement constants, k_p and k_r respectively, of native and treated proteins by increasing the pressure applied. Those results were linked to the reduced interfacial activity of treated pea proteins, resulting in weaker interactions and compromised emulsion stability. This research offers valuable insights into the impact of HPH treatments on pea proteins, shedding light on interfacial behavior under different processing conditions. Moreover, by elucidating the interplay between HPH treatment, pea proteins, and emulsion stability, this research advances the comprehension of protein-based emulsion systems and interfacial engineering approaches.

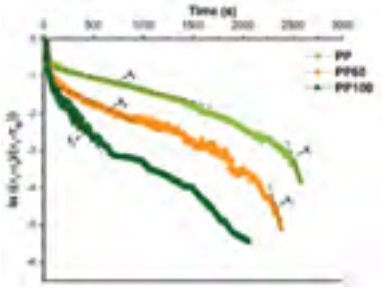

Figure 1. Kinetic plot for native and treated pea protein samples (PP, PP60 and PP100) at a nominal concentration of 1 g/L, and corresponding fitting of penetration and rearrangement constants (k_p and k_r) obtained from the linear regression analysis of the first and second slope of the kinetic model.

Acknowledgements: This research was funded by the European Union – Next Generation EU. Project Code: ECS00000041; Project CUP: C43C22000380007; Project Title: Innovation, digitalization and sustainability for the diffused economy in Central Italy – VITALITY.Inizio modulo

Bulk and interfacial behaviour of sustainable plant protein-based microgels

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ABSTRACT

Microgels are deformable particles of cross-linked solvated polymers, with tuneable viscoelasticity for bulk media. Additionally, some proteinaceous microgels possess excellent interfacial properties, such that they are partially wetted by both oil and water phases and thus have the ability to act as Pickering stabilisers[1]. This study focuses on understanding the performance of plant protein microgels by changing their protein concentration. Potato protein (PoP) was used to produce microgels of sub-micron diameter via a top-down approach of thermal crosslinking followed by high-shear homogenisation of the bulk gel. Bulk 'parent' gels were studied at protein concentrations of 5, 10, 15, and 18 wt%, varying in their shear elastic moduli by several orders of magnitude (1 -100 kPa) and diameters of 100 to 300 nm, as observed via dynamic light scattering and atomic force microscopy (AFM). Interfacial rheological measurements (interfacial shear moduli G'_i, G''_i) and interfacial tension (γ) of adsorbed PoP and PoP microgels (both at tetradecane-water interfaces) were combined with bulk rheology of the microgel dispersions and AFM of adsorbed microgel films to assess the relationship between microgel size and modulus on bulk and interfacial properties.
The results demonstrated that PoP microgels were capable of lowering γ at the oil-water interface to values ≈ 22 mNm^{-1}, similar to those of native PoP. Microgel dispersions (≥ 50 vol%) showed significant bulk viscosity and shear thinning properties, unlike non-microgelled PoP. Preliminary results from the interfacial shear rheology suggested the importance of the deformability and size of the microgels in terms of packing at the oil-water interface to facilitate an optimal level of interfacial elasticity. Furthermore, temperature variation studies provided an insight into a means of tailoring microgel interfacial elasticity. Thus process-induced tuning of plant protein-based microgels offers a new platform for the development of responsive Pickering emulsions to tackle a multitude of industrial challenges.

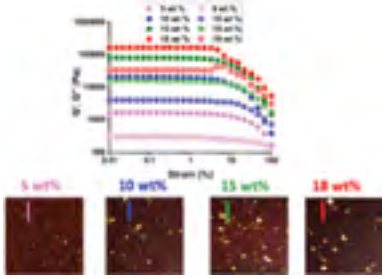

Figure 1. Viscoelasticity of the bulk 'parent' gels and topographic images showing size and shape of the microgels produced from parent gels at these concentrations.

References: 1. Akgonullu, D. Z.; Murray, B. S.; Connell, S. D.; Fang, Y.; Linter, B.; Sarkar, A., Synthetic and biopolymeric microgels: Review of similarities and difference in behaviour in bulk phases and at interfaces. *Adv Colloid Interface Sci* 2023, *320*, 102983.

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Chitosan-Alginate Microgels as emulsifiers for functional foods applications

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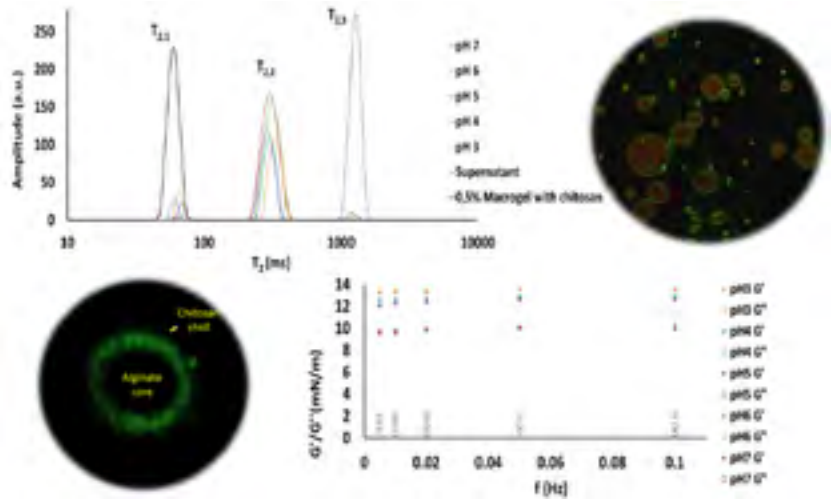
ABSTRACT

Microgels are intriguing colloidal entities that exhibit properties of both particles and hydrocolloids. In the recent years, there has been a growing interest in exploring the potential of microgels to serve as emulsifiers. This study focuses on the relationship between the interfacial, structural, and physicochemical attributes of alginate-chitosan microgels in comparison to the emulsion properties. Additionally, in order to overcome the problem of the relatively high hydrophilicity of the microgels as emulsion stabilizers, an additional set of experiments was conducted with hydro-cinnamylated chitosan, a hydrophobically modified derivative of chitosan. The microgel interfacial properties were characterized via dynamic interfacial tension and dynamic interfacial rheology measurements at the oil/water interface. In addition, their size and structure was determined using laser diffraction, confocal laser microscopy (CLSM), and time-domain nuclear magnetic resonance (TD-NMR). The potential of time-dependent swelling of the microgels was also determined via TD-NMR. The results showed that the pH value exerts a notable impact on the size distribution of microgels, with higher pH values leading to smaller particles for the alginate-chitosan microgels. Spin-spin relaxation (T2) measurements via TD-NMR suggest that the size increase may be attributed to swelling. In the dilatational rheological interfacial measurements, particles formed at lower pH levels presented higher E′ and E″ values, which was attributed to the larger sizes of the particles forming a thicker viscoelastic interfacial layer. The influence of the particle properties on the dynamic interfacial tension was minor. Emulsion characteristics and stability were significantly influenced by the microgel properties, with lower pH systems resulting in notably smaller sizes and improved stability. The study concludes by discussing the correlation between interfacial and structural properties and their impact on emulsion characteristics.



Acknowledgements: This research has been financed by the OLIE group, Department of Food Science and Technology, International Hellenic University.

Exploring and understanding food emulsion systems with neutron scattering and spectroscopy

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ABSTRACT

Food emulsions may be either stabilzed by amphiphilic milk-based and sustainable plant-based proteins. The protein is affecting the interfacial and emulsion stabilization mechanisms on a macro- and microscale of length and time. To understand these mechanisms in detail different length scales from interatomic to macroscopic distances as well as time dependent mechansims need to be investigated.

Neutron scattering techniques provide insight into such emulsions on these length scales depending on the technique used. Combining structural information on molecular length scales from small angle x-ray and neutron scattering (SAXS and SANS) with time dependent neutron spin echo spectroscopy (NSE) allows to expand our understanding towards intermolecular interactions within the interface. These interactions are linked to the emulsion stability – the elastic properties of the protein or protein/phospholipid stabilized oil/water interface on molecular length scales.

NSE provides in this combination the time dependent correlation function in reciprocal space, S(q,t), on molecular length scales and time scales in the nanosecond range relevant for thermally driven motion of mesoscopic systems such as the emulsion interfaces.

This presentation introduces the neutron and x-ray scattering techniques which broadens the classical characterization of food emulsions. Results from emulsions stabilized with b-lactoglobulin as a representative milk protein, and different plant-based proteins, are presented and discussed. Contrast variation by deuteration of some components of the emulsions is applied to focus on the interfacial region, relying on the uniqueness of neutrons.

Connecting these emerging results with classical characterizations such as interfacial tension or viscoelasticity helps understanding the complex mechanisms of interfacial stability and may contribute to a knowledge driven development of sustainable food emulsions.

Novel Ways to Study Interfacial Lipid Crystallization

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ABSTRACT

Lipid crystals, such as monoglycerides, are a type of colloid particle that provide stability in many food emulsions including milk, cream, or butter. Additionally, monoglycerides are indigenous to many oils and can also be added to alter the texture and stability of food products.

Since monoglycerides are amphiphilic, they can adsorb at an oil-water interface. Unlike typical small molecule surfactants, monoglycerides undergo phase transition during the temperature cycling. At certain temperatures monoglycerides start to crystallize. Their crystallization occurring specifically at an oil-water interface is of particular interest, as the stability of an emulsion can be enhanced through a Pickering-like mechanism. However, stability can also be compromised through partially coalesced fat globules.

In this research, we have employed novel technique to characterize both bulk and interfacial lipid crystallization, including Synchrotron Small – and Wide – Angle X-ray Scattering (SAXS/WAXS). By using our approach of an isolated oil-water interface, it can be determined where the monoglyceride crystals are located, in relation to the interface. Moreover, their concentration and polymorphic form can also be determined.

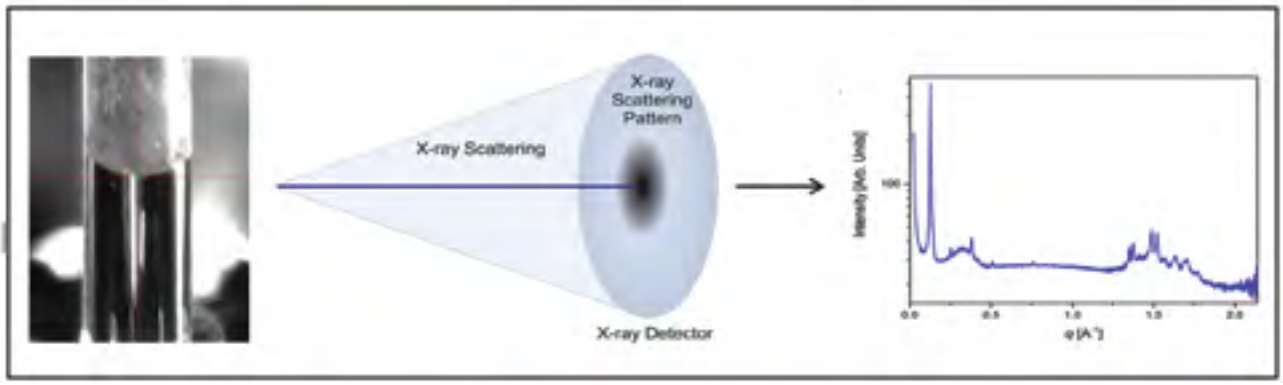

Figure 1. Synchrotron Small – and Wide – Angle Scattering (SAXS/WAXS) of isolated oil-water interface, with capillary containing crystallizing lipids.

12. SUSTAINABLE FOOD COLLOIDS CLEAN, ENVIRONMENTALLY FRIENDLY, PLANT-BASED III

How plant protein characteristics affect rheological and lubrication properties

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ABSTRACT

Plant proteins are applied in various foods as an alternative for animal proteins, including meat analogues, vegan cheeses and plant-based beverages. However, the perception of such products often deviates from the original counterpart, due to differences in physicochemical properties. It has been acknowledged that many texture attributes, such as smoothness, creaminess, and fattiness, are not only related to the rheological properties of the food, but lubrication aspects are also important. Currently, there is still limited knowledge how different plant proteins impact lubrication. Therefore, the aim of this study was to investigate how plant proteins affect lubrication behavior, specifically in relation to their dispersibility and particle size distribution.

In our study, the aggregation level of different plant proteins (pea, soy, fava, potato) was determined to quantify the ratio between dispersible (soluble) and non-dispersible fraction. Potato showed the highest degree of dispersibility, and pea protein exhibited the lowest dispersibility. This characteristic had a large effect on the lubrication behavior. For all protein types, the dispersible fraction with a low aggregation degree and small size (<1 µm) exhibited lower friction coefficients (better lubrication) than non-dispersible aggregates (typically 70-100 µm) at the same protein concentration. To improve the lubrication properties of non-dispersible aggregates, we modified the aggregation level of the aggregates by homogenization. The reduction in size indeed effectively reduced the friction coefficient, especially at 400 bar. Lubrication efficiency was thus irreversibly related to particle size. However, size could not explain all differences found between the different proteins, indicating that not only the size, but other factors also play a role. These findings will provide us with valuable insights to us which will be useful in optimizing the application of plant proteins and improving the palatability of plant protein foods in the future.

Future meat replacers obtained using ancient fermentation techniques

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ABSTRACT

A broad range of plant-based meats have been developed in recent years and are currently widely available. However, a consumer demand is arising for plant-based products with minimal processing and limited additives. This offers many scientific challenges and opportunities for innovation. In this presentation, we explore the potential of solid-state legume fermentation to obtain food materials that have consumer-acceptable flavour and textural attributes. The resulting legume mass is combined with binder which vary in their binding abilities (e.g. strength) including methylcellulose (MC), gluten and (vegan) egg and moulded into a burger patty. Using this legume/binder matrix we display how the molecular properties and functionality of binders affect the textural properties of fermented legume patties. The results from a trained sensory panel show that the reference sample with no added binder is *moist* with limited *cohesiveness*, *density*, and *firmness* and has an umami flavour. The sensory *firmness* and *density* become highest upon the addition of 5% MC. This is in line with fluorescent microscopy images for this sample, which show a dense network as well as texture profile analysis (TPA) and rheological results as this sample displays the highest values in terms of hardness and viscosity, respectively. However, the *moistness* of the sample with added MC strongly decreases and the *legume* flavour increased with the addition of MC as determined by a trained sensory panel. Highest values for *moistness* paired with *savoury* and *roasted* flavours are found upon the addition of vegan egg. By combining the fermented legume mass with different binders, the texture of fermented legumes can be enhanced in terms of firmness, moistness and density leading to improved sensory properties. Fermented legumes may thus be suitable candidates for a new generation of plant-based proteins with limited processing and additives.

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Rheological properties and possible application of alkali-extractable wheat bran arabinoxylans as affected by their structural heterogeneity

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ABSTRACT

Arabinoxylans (AXs), are characterized by several physicochemical properties, including the abilities of increasing viscosity of aqueous solutions, formation of gels and emulsification activity [1]. The alkali treatment which is commonly used for AXs extraction from cereal brans, depending on the intensity, might affect the structural characteristics of AXs, i.e., the molecular weight (Mw), the arabinose to xylose (A/X) ratio, and the content of the attached feruloyl groups on the polymer chains, possibly impairing some of their physicochemical properties [2]. Therefore, NH_4OH and NaOH solutions were tested in combination or separately, for their effectiveness as extraction media of AXs from wheat bran (WB), following two schemes of extractions, the first one by employing combinations of pre-treatment with NH_4OH (pH 9.5, 25 °C / 0, 0.5, 1 and 2 h) followed by a subsequent extraction with 0.1 M NaOH (60 °C / 0, 1, 2, and 4 h) and a second one by employing separate treatments with NH_4OH or NaOH at pH 8.5, 9.5, 10.5 and 11.5 for 2 and 4 h at 60 °C. The molecular characterization of the fractions, by means of HPLC-SEC-RI, HPLC-MS and 1H NMR revealed structural heterogeneities, regarding the Mws, the A/X ratio and the presence of ferulic acid, which were reflected to their rheological properties. For instance, AXs of higher Mws were obtained using NaOH instead of NH_4OH at lower pH levels or by combining NH_4OH pretreatment with NaOH treatment. Additionally, at high pH levels only the samples treated with NH_4OH were able to retain the ferulic acid on their structures at levels that allowed these molecules to form gels by enzymatic cross-linking. Therefore, selected AX fractions can be successfully implemented into acid – set skimmed milk gels to improve their texture or used in the development of mixed hydrogels (with cellulose nanocrystals) with modified mechanical properties.

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Towards the understanding of the structure deformation behavior of meat and meat analogues

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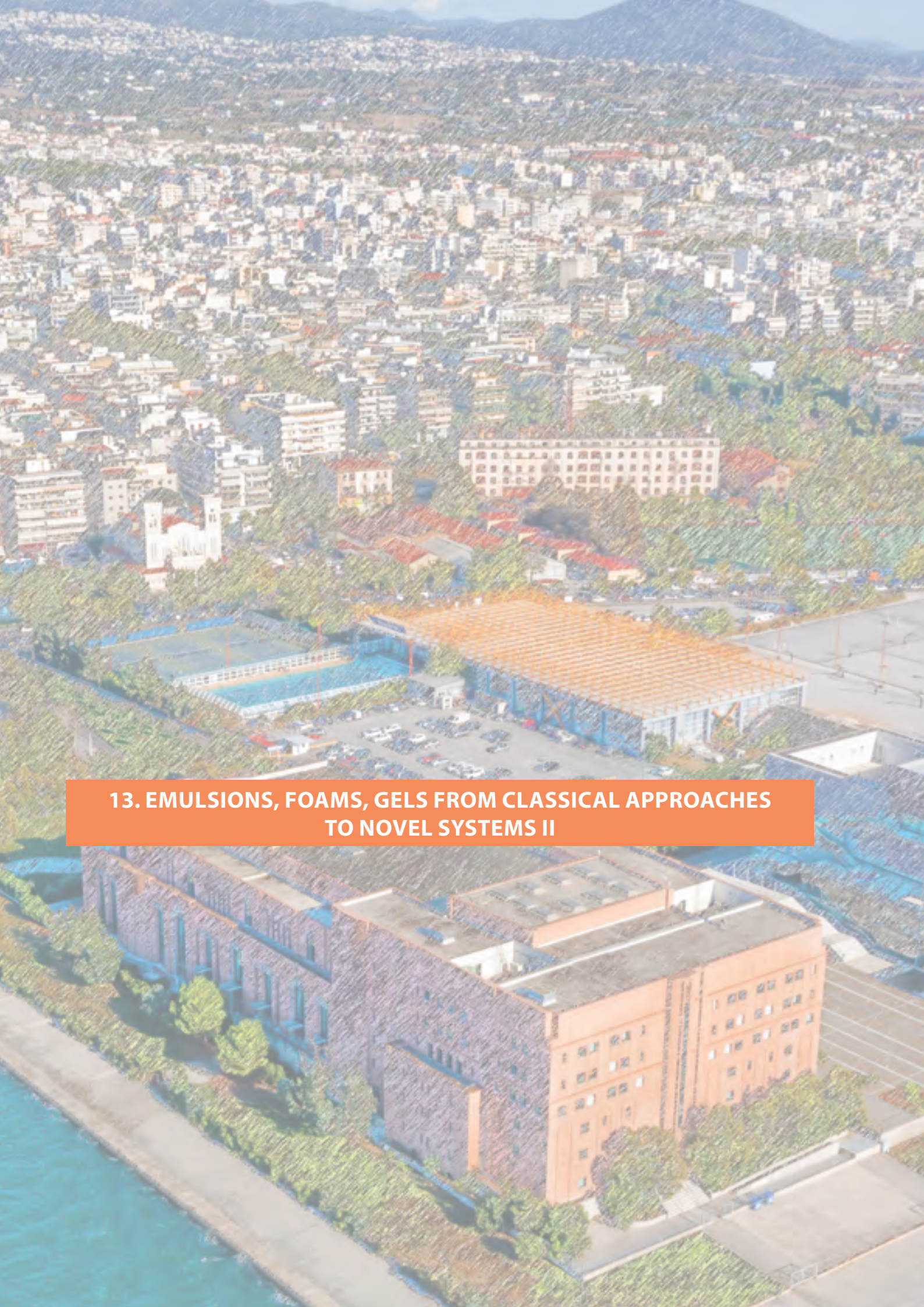
ABSTRACT

Meat analogues made from plant proteins are a sustainable alternative to meat but lack the same textural properties, hindering the achievement of a similar sensory experience. Current efforts to mimic the visual and textural properties at a macro scale do not fully replicate the irreversible structural deformation of meat during the first bite. Thus, this study aims to address these gaps and explore the structure-texture relationships of meat and meat analogues using a multi scale approach. The objective of this study is to develop a model that elucidates the differences in deformation behavior between meat and meat analogues, providing insights into their structural and textural properties.

To quantify the mechanical anisotropy, samples were cut lengthwise and crosswise to the fibers' direction and the Warner Bratzler shear force (WB) was measured. Texture properties such as hardness and springiness were assessed using texture profile analysis (TPA). The rheological properties, including loss and storage modulus (G', G''), as well as the linear viscoelastic region (LVE), were measured using rheometry. The meso scale structure characterization was performed using scanning electron microscopy (SEM). Additionally, samples were deformed with compression and strain, and the resulting structural changes were examined using SEM.

Meat analogues displayed anisotropy at a macro scale, as evidenced by the directional dependence of shear force and springiness. In contrast, meat exhibited isotropy on a macro scale, showing no directional dependencies. Meat analogues demonstrated a longer linear viscoelastic region (LVE), which was associated with their high springiness. Furthermore, it was observed that the LVE region correlated with the degree of structure deformation at a micro scale.

These findings contribute to a deeper understanding of the textural properties of meat analogues and their ability to mimic the properties of meat.



13. EMULSIONS, FOAMS, GELS FROM CLASSICAL APPROACHES TO NOVEL SYSTEMS II

Development and characterization of a novel oleogel-in-oleogel system with tailorable digestibility

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ABSTRACT

Saturated fats have the unique property of forming solid, crystalline structures at room temperature, making them invaluable for the food industry. Despite these remarkable structural properties, along with their enticing sensory qualities, saturated fats have a weak effect on inducing satiety, which can lead to passive overconsumption, contributing to obesity and related comorbidities. Addressing these concerns involves reducing saturated fat intake, by replacing them with oleogels rich in unsaturated fatty acids. However, most conventional oleogels possess a high caloric content, not providing a comprehensive solution to overconsumption and related issues.

Our study aimed to develop a novel oleogel-in-oleogel system with partial indigestibility, designed to slow down the digestive process, induce satiety, aid in weight management, and deliver essential fatty acids. To accomplish this, we developed in-house equipment capable of creating oleogel beads, with the goal of introducing kinetically entrapped oil within a second oleogel. The inner oleogel, gelled by ethylcellulose, a cellulose derivative with gut effects similar to dietary fiber, is expected to act as an inert component, passing relatively unaltered to more distal parts of the gastrointestinal tract. Meanwhile, the system retains its capacity to deliver essential fatty acids, thanks to the digestible outer oleogel, gelled by conventional gelators. The oleogel-in-oleogel was compared to conventional multi-component oleogels with the same composition. The oleogel-in-oleogel exhibited no alteration of the melting profile after addition of the oleogel beads. Using the INFOGEST protocol adapted for oleogels by our research group, the kinetical confinement was proven to allow the tailoring of the *in vitro* digestibility of the oleogel, reducing it by 17%-26% compared to the control oleogels and up to 33% compared to single-component oleogels. These results indicate great promise in envisioning oleogels not only as saturated fat substitutes, but also as a possible solution for controlling satiety and as bodyweight management tool.

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Emulsions stabilized by plant proteins for the encapsulation and delivery of bioactive compounds in foods

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ABSTRACT

In recent times, there has been a shift towards substituting animal proteins with plant-based alternatives to reduce consumption of animal products. Plant and algae proteins have been gaining popularity in the food industry because of their emulsifying properties, aligning with current scientific exploration of plant-based products [1,2]. In our ongoing project, we focused on stabilizing emulsions using proteins, specifically pea and soy protein isolates, as well as phycocyanin for encapsulating bioactive substances. We employed and compared two different homogenization methods: high-shear and high-pressure homogenization. Protein particles were created using the pH-shifting technique, and their effectiveness as stabilizers was tested in two scenarios: immediately after pH shifting and after passing through the high-pressure homogenizer. We experimented with various protein concentrations and different oil volume fractions. Extra Virgin Olive Oil and Sunflower Oil were chosen for emulsion preparation. We measured the size and ζ-potential of the particles using Dynamic Light Scattering and examined the emulsions both macroscopically and microscopically with optical and confocal microscopes. The size and ζ-potential of the particles were measured using Dynamic Light Scattering while stability over time was monitored using the Creaming Index. Emulsions were examined both macroscopically and microscopically using optical and confocal microscopy. The interfacial properties of the proteins were also evaluated. High-pressure homogenization significantly enhanced emulsion stability. Furthermore, we fortified the emulsions with lipophilic antioxidants such as α-tocopherol and squalene, characterizing their structure. Finally, we evaluated both the empty and loaded emulsions for their antioxidant capacity using the DPPH assay. The results demonstrated that both systems exhibited strong scavenging effect against free radicals. In summary, these innovative emulsion systems have the potential to serve as carriers for bioactive compounds, while also possessing inherent antioxidant abilities due to the presence of proteins in their structure.

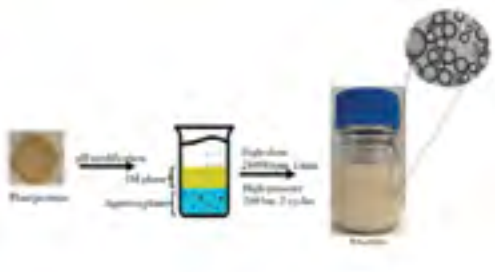

Figure 1. Schematic representation of Pea protein Isolate emulsion formulation

References: [1] E. Galani et al., "Pea and soy protein stabilized emulsions: Formulation, structure, and stability studies" Food Colloids II, 7 (2), 30, 2023

[2] E. Galani et al., Fungi-derived chitosan as an emulsion stabilizer for the encapsulation of bioactives, COLSUA, 2023, (Submitted).

Texture modulation in plant-based high-protein yogurt alternatives: Adjustment of the texture by addition of oil and pectinbased microgel particles

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ABSTRACT

Yogurt, a fermented milk product, is an important part of many people's daily diet. In recent years, there has been a surge of interest in a vegan diet for ethical, moral and health reasons. In the vegan diet, pea protein is an interesting alternative raw material to dairy because it contains all eight essential amino acids, is allergenfree and is also suitable for the preparation of vegan yogurt alternatives.

Not only vegan but also high-protein products have been increasingly sought after by consumers over the last years. High-protein yogurts are often perceived as too firm as well as sandy. This is even more true for vegan high-protein yogurt alternatives, e.g. from pea protein, due to the specific gelling properties of the vegetable proteins. Consequently, it is important to understand how the texture in fermented pea protein gels can be modulated.

The effect of rapeseed oil and microgel particle addition on the texture of fermented pea protein gels with increased protein concentration was investigated. The addition of oils and fats to yogurt alternatives typically improves the lubricating properties of the gel matrix and thus improves the creaminess perception. However, finely dispersed oil droplets also increase the viscosity and gel strength, thus making the yogurt alternative perceived as even firmer. Pectin-based microgel particles, have been found to reduce both features in fermented soy matrices as they acted as inactive fillers. It was thus hypothesized that the combination of both additives – rapeseed oil and microgel particles – can improve the lubrication of pea protein yogurts while at the same time reducing the viscosity and gel strength.

In the contribution it will be shown that the addition of various concentrations of rapeseed oil improved the lubricating properties as well as the color of the yogurt alternative, but increased the viscosity. The addition of the pectin-based microgel particles of 1 µm in size decreased the viscosity of the yogurt alternative without negatively affecting the lubricating properties. The yogurt alternatives were characterized rheologically as well as tribologically. The results show strategies to increase the consumer acceptance of vegan yoghurt alternatives by improving the texture of high-protein products.

Figure 1. Texture modulation by addition of oil and pectinbased microcrogel particles

Acknowledgements: This research was funded within the frame of IGF Project no. 21325 N of the FEI is/was supported via AiF within the programme for promoting the Industrial Collective Research (IGF) of the Federal Ministry of Economic Affairs and Climate Action (BMWK), based on a resolution of the German Parliament.

Impact of effective volume fraction and ion concentration on rheological properties of low acyl gellan gum fluid gels

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ABSTRACT

Fluid gels are jammed suspensions of soft gel particles dispersed in a low-viscosity continuous medium (1). They can be obtained by applying shear to a gelling hydrocolloid during its sol-gel transition (2). Fluid gels found application in food industry as suspending agent, viscosifier, foam and emulsion stabilizer thanks to the tunability of their rheological properties. However, little is known on the impact of fluid gel particle effective volume fraction on fluid gel rheology. In this study we investigated the effect of effective particle volume fraction on G' and yielding properties of calcium-aided low acyl gellan gum fluid gels processed at different biopolymer concentrations while keeping processing conditions and biopolymer/calcium ratio constant. Furthermore, we studied how calcium concentration modifications after fluid gel formation impacts G' and yielding properties of low acyl gellan gum fluid gels. A method to measure the free calcium in fluid gels was developed. In the plots of G' vs the effective particle volume fraction, we observed the presence of a "kink" (or sudden slope change) which is suggestive of a core-shell particle behavior. In addition, a "kink" in yield strain was observed in all the fluid gels analyzed. Fluid gels with a lower biopolymer concentration showed higher yield strains which can be due to a softer microstructure and a rougher particle surface, easing interparticle entanglement. We also observed that calcium concentration after fluid gel formation impacts the final properties of fluid gels, which we attribute to a change in calcium-COO^- interaction equilibrium. Finally, we found that the ratio between free and bound calcium remains constant when the gellan to calcium concentration is kept constant in the formulation. This study helps gaining knowledge on how physical and physicochemical parameters affect fluid gels' rheology to potentially tune their properties for specific applications.

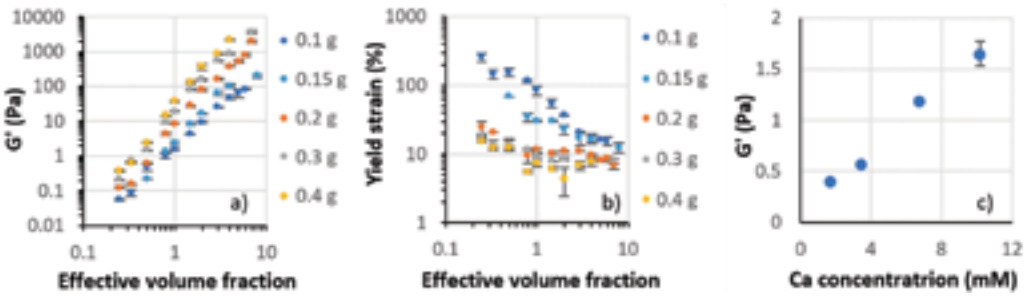

Figure 1. Impact of effecting volume fraction on a) G' and b) yield strain. c) Impact of Ca concentration after fluid gel formation on G' of a 0.1 % low acyl gellan gum fluid gels gelled with 3.4mM $CaCl_2$ $2H_2O$.

References: 1. D'Oria, G., Gunes, D. Z., Lequeux, F., Hartmann, C., Limbach, H. J., & Ahrné, L. (2023). Fluid gels' dual behaviour as granular matter and colloidal glass. Food Hydrocolloids, 137, 108401. https://doi.org/10.1016/j.foodhyd.2022.10840

2. D'Oria, G., Zeng, X., Limbach, H. J., Hartmann, C., Ahrné, L., Gunes, D. Z. Effect of shear on low acyl gellan gum fluid gels' rheology, particle morphology and physical ageing. Under revision in Food Hydrocolloids.

Acknowledgements: The research was funded by Société des Produits Nestlé.

Effect of complementary polymer on starch microsphere preparation in aqueous two-phase systems

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ABSTRACT

Starch microspheres (SM) is interesting for several food applications, such as microencapsulation and controlled release of supplements. SM can be prepared at moderate temperatures in emulsified aqueous two-phase systems (ATPS) composed of hydrolysed starch and another polymer, without any need for organic solvents or chemical cross-linkers. Another benefit is that water-in-water emulsions exhibit a low interfacial tension, compared to water-in-oil emulsions. These benefits make the concept of SM preparation through ATPS promising for microencapsulation of sensitive cargo, such as probiotics. However, both starch crystallisation and ATPS phase behaviour are complex and can be affected by several factors, such as choice of complementary polymer and temperature conditions. There is limited knowledge of how different polymers can affect the phase behaviour, SM formation, and encapsulation. Therefore, this work has investigated ATPS SM preparation with different complementary polymers at a constant temperature.

Starch-ATPS with complementary polymers of different sizes and types were assembled to study phase behaviour, SM formation, and SM properties. The investigations showed that polymer size had minor effect on phase behaviour, but the viscosity of the continuous phase had a key role in the SM formation. Here, too low viscosity impaired the stability of the dispersed starch phase droplets, while too high viscosity limited appropriate amounts of dry matter to be mixed into the ATPS. Moreover, complementary polymer type had a notable effect on ATPS phase behaviour as well as SM formation, with regard to factors such as crystallisation kinetics, aggregation, and size of the SM (see Figure 1). Even though these differences during the preparation process were evident, other SM properties, such as crystal type and thermal stability, appeared to stay similar.

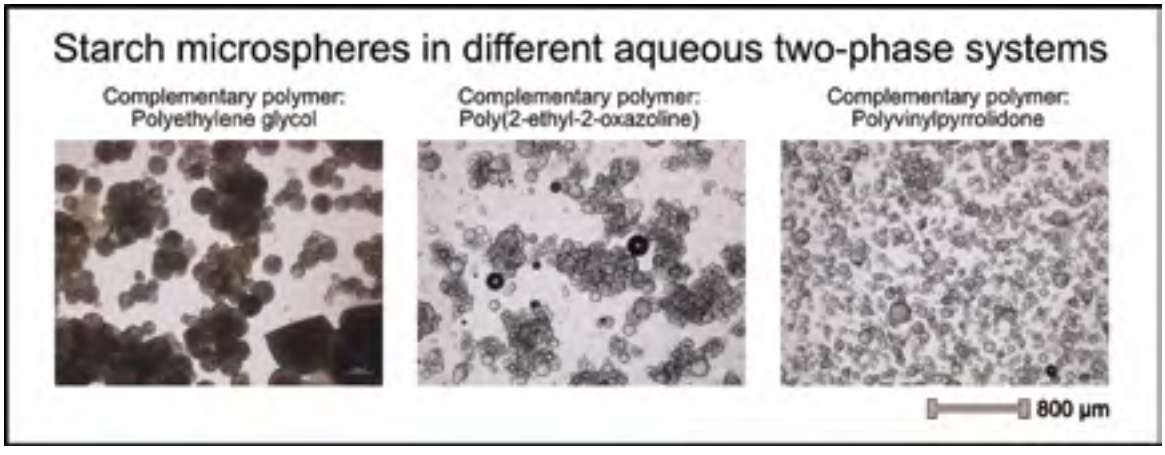
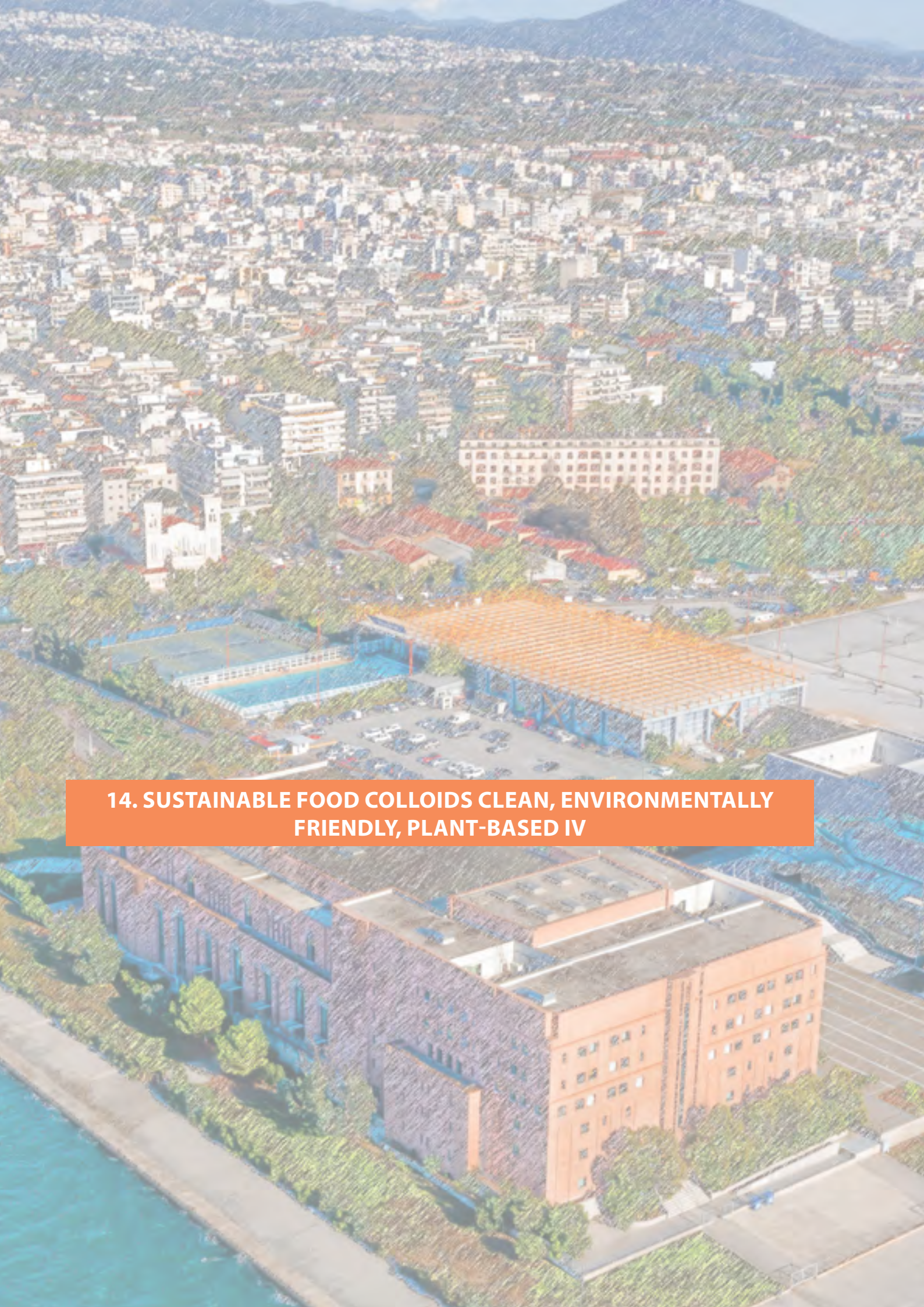


Figure 1. Light microscopy captures of starch microspheres during preparation in aqueous two-phase systems with different complementary polymers. The captures are taken 24 hours after mixing the starch with the polymer solution.

Acknowledgements: We acknowledge the Swedish Foundation for Strategic Research for founding of Zandra Gidlöf (Grant number FID18-0026). This research was also financed through Competence Centre NextBioForm, funded by Vinnova Swedish Governmental Agency for Innovation and The Swedish

Research Council under grant number 2018-04730.



14. SUSTAINABLE FOOD COLLOIDS CLEAN, ENVIRONMENTALLY FRIENDLY, PLANT-BASED IV

Microstructural and conformational changes of interfacial and biopolymer stabilizers drive the difference between dairy and plant-based cappuccino foams

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ABSTRACT

Many people enjoy a good cup of coffee as a part of their daily routines, whether as part of social rituals or as an energy boost. If you are someone like me who is relatively new to coffee you might take your coffee with milk, preferably foamed. However, the fact that food production contributes approximately 26% of annual greenhouse gas emissions means that many people are looking to dairy alternatives for their cup of coffee. A consistent complaint is that plant based dairy alternatives "cappuccino" foams are much drier and are unstable compared to dairy particularly when prepared at home. If we are to have a sustainable shift from animal to plant-based products, we need to understand how such products can deliver in terms of functionality as well as sustainability.

The following presentation presents how the stabilizer molecular properties and aeration processes impact the colloidal stability and foam stabilization capabilities of dairy (alternative) milks. It starts by explaining the origins of the colloidal stability of plant/dairy protein stabilized emulsions in acidic/mineral rich coffee. It then examines how different foaming processes (whisking/steam injection) impact the conformation of plant/dairy protein interfacial stabilizers and the biopolymer viscosifier. Key results highlight that colloidal stability is not different between plant and dairy proteins, but related to their interfacial conformation. Whisking aeration led to 25% larger average bubble size and 20% higher foam air incorporation, which was related to differing aeration hydrodynamics. Foam drainage kinetics were markedly different between whisking and steam injection aeration processes, which was related to the effects that steam injection had on the biopolymer viscosifier. Finally, SRCD we were also able to get a first insight into the effect that foaming has on protein folding. These understandings are helping to close the gap between dairy and non-dairy cappuccino foams.

Acknowledgements: This work was funded by Society des Produits Nestlé S.A.

Quantitative Image Analysis of Protein and Lipid Oxidation Localization in Oil-in-Water Emulsions Prepared with Legume Protein Isolates

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ABSTRACT

In traditional high-fat oil-in-water emulsions like mayonnaise, egg yolk acts as the stabilizing agent. However, the unsaturated fatty acids in these emulsions are prone to oxidation, leading to a reduced shelf life. Egg yolk contains substances that accelerate this oxidation process, particularly at the oil-water interface, where emulsifying proteins are present. This interface is a hotspot for lipid oxidation and the formation of protein free radicals, which, in turn, can promote lipid oxidation within the emulsion droplets. With a growing demand for environmentally sustainable food options, the use of animal-based ingredients like egg yolk in food production is being questioned. Plant-based proteins have emerged as a promising alternative. Yet, our understanding of oxidation in emulsions containing plant-based proteins is limited.

Our research employs confocal laser scanning microscopy (CLSM) in combination with the oxidation-sensitive fluorescent dye BODIPY 665/676 to track oxidation in emulsions made from soy, pea, and faba protein isolates. Using quantitative image analysis in Python, we investigate how specific plant-based proteins influence oxidation distribution in these emulsions. The image analysis results are validated with NMR measurements of the accumulation of hydroperoxides and aldehydes, both oxidation by-products.

In summary, our study delves into the mechanisms of oxidation in plant-based emulsions, shedding light on the oxidative stability of plant-based food products and aiding in the improvement of their formulations.

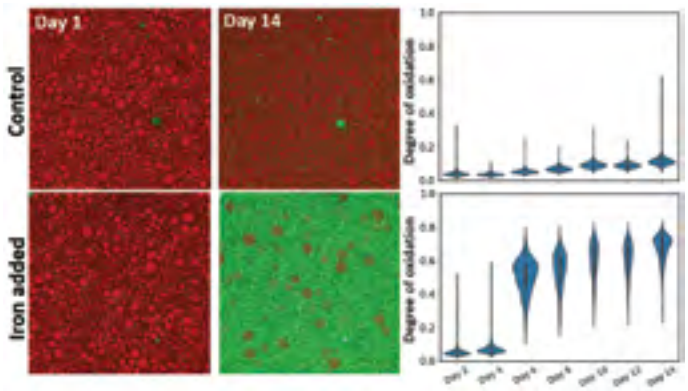

Figure 1. CLSM images illustrating the progression of oxidation in a soy protein isolate-based emulsion, comparing samples with and without added iron EDTA (control). These images reveal the emulsion's state after one and 14 days of storage at 30°C), with red and green colors representing non-oxidized and oxidized BODIPY, respectively. We assess oxidation by calculating for every individual droplet the ratio of non-oxidized intensity to total fluorescence intensity (right graphs).

Acknowledgements: This work is part of the project LocalBioFood of the research program Science PPP Fund.

Soybean fibers : a plant-based by-product for stabilizing emulsions

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ABSTRACT

During the industrial treatments of soybean, various co-products are obtained. Here, we present some new results obtained on the composition and functionality of one of these co-products: soybean fibers - often named 'okara' – that we disperse here in a vegetable oil.

We have both investigated the chemical composition of the raw fibers and their morphology (by SEM), as well as for selected samples of that material separated by fiber sizes.

Once the fibers are dispersed in oil and then mixed with water, we have identified under which conditions emulsions can be obtained: the proportion of oil and water and the fiber concentration and sizes are widely varied, and the viscoelasticity of the resulting emulsion is then monitored by rheometry.

Surprisingly, we find a large range of possible texture with very different viscous or elastic behavior. In particular, we show that very stable and elastic emulsions can already be obtained while the fraction of oil remains as low as 20%. Complementary studies with different microscopic methods allow us to better understand the structure of these non-classical emulsions, evidencing that large fibers are actually transferred from the oil to the water phase during the emulsification process, thus leading to a complex viscoelasticity of the continuous water phase. These results are also compared to other vegetable fibers (from pea and oat) of different sizes, eventually showing the various advantages of this soybean by-product.

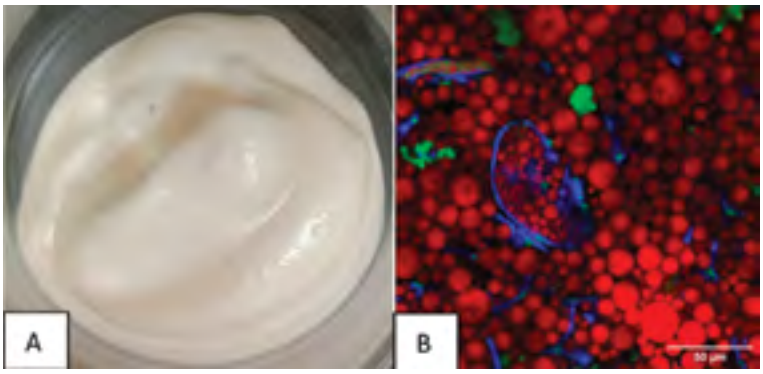

Figure 1 (a) : photography of an emulsion with 6,5% of soy fibers and a oil/water ratio of 50/50 and (b) confocal laser scanning microscopy image of an emulsion with 6,5% of soy fibers and a oil/water ratio of 50/50.

Blends of vegetable oils as a tool to tune the texture

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ABSTRACT

Nowadays, consumers are turning towards vegetarian and vegan products as part of a more sustainable approach than animal-based products. Fat-containing products are important components in our daily life and thus food, pharmaceutical and cosmetic industries are keen to find alternatives fats from plant sources. The role that fats plays in material functionality, flavor perception, texture and health characteristics are in large part due to their physical properties. Blending is often used to design oils and fats for specific applications and is also the most practical and affordable method to achieve specific properties.

The aim of the proposed work was to characterize graded binary and ternary blends of cocoa butter (CB), copra oil (CO) and high oleic sunflower oil (HOSO). The two former fats are solid at room temperature whereas the last is liquid. Fat blends with different compositions were crystallized at 4°C and then characterized using various techniques including Nuclear Magnetic Resonance spectroscopy (NMR) for the determination of solid fat content (SFC), optical microscopy with polarized light together with SAXS and WAXS to determine the structure and organization and penetrometry to assess mechanical behavior. Both binary CB/HOSO and CO/HOSO blends displayed good compatibility, with a monotectic behavior for CB/HOSO blends, whereas CB/CO mixtures as well as CB/CO/HOSO displayed eutectic behavior between 10 °C and 25°C. The eutectic behavior persists, being nevertheless shifted, under long-term storage at 4°C [1].

These fats can also be dispersed in water to form oil-in-water emulsions that may lead to a gelling after crystallization (see Fig. 1). We show the important role of the chosen stabilizer in the occurrence of this gelling and discuss gelling mechanism.

Figure 1: two different textures obtained with emulsions containing bends of vegetable fats

References: [1] Julie Bloquet-Maurras, Ahmed Bentaleb, Eric Laurichesse, Mathilde Bayard and Véronique Schmitt «Impact of aging on the phase behavior of cocoa butter and copra oil blends» *Food Chemistry Advances* **3** (2023) 100412

https://doi.org/10.1016/j.focha.2023.100412

19TH FOOD COLLOIDS CONFERENCE

USING COLLOID SCIENCE TO FIND NEW SUSTAINABLE SOLUTIONS IN FOOD

POSTER PRESENTATIONS

P1. FOOD COLLOIDS IN NON-[OR CLOSE TO] FOOD APPLICATIONS NUTRACEUTICS, PHARMACEUTICS, PACKAGING, MEDICINE

Antimicrobial films from zein nanoparticles with carvacrol 48

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ABSTRACT

Zein is water–insoluble plant protein with film–forming properties, which can be used for the preparation of biodegradable films with great potential for sustainable food packaging. Zein films can be additionally functionalized by addition of different active substances, such as antimicrobial or antioxidative agents In this study, zein films were prepared from dispersions of zein nanoparticles encapsulating carvacrol, using pseudolatex technology. Carvacrol is a phenolic monoterpene, with antimicrobial and antioxidant properties, and it was used as a model lipophilic antimicrobial agent. Influence of carvacrol on properties of zein films was tested. Encapsulation efficiency of carvacrol in zein films and its release profiles were determined. Antimicrobial activity of zein films with the highest carvacrol concentration (20% wt.) was tested under dynamic conditions. It was shown that continuous zein films can be prepared by coalescence of zNC, using pseudolatex technology. Results showed that tested carvacrol concentrations have little to no effect on zFc properties. Antimicrobial activity of zFc was found to be sufficient to block the growth of gram-positive bacteria.

Impurity-free production of submicrometer-sized nutraceuticals by ultrashort pulsed laser fragmentation in liquids 113

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ABSTRACT

One of the most challenging issues in formulation development of nutraceuticals is that although the ingredients may be highly effective at their target site they have low solubility in relevant aqueous media, which results in impaired bioavailability following oral uptake. Therefore, strategies to increase the solubility of these hydrophobic substances are in high demand. Particle size reduction down to the sub-micrometer scale is a well-known method that increases the total surface area, which in turn results in improved dissolution properties and better oral absorption, without the need for additives causing undesirable side effects.[1]

Laser fragmentation in liquids (LFL) of suspended microparticles (MP) is a promising downsizing method that has been known for years and is ideally suited for the production of highly pure sub-micrometer and nanoparticles, which are obtained in aqueous solutions and are thus directly available as stable colloids.

Even though this method has been known for decades, limited scalability of the process and particularly the direct correlation between chemical degradation and long processing times and the related high number and variability of pulses per particle in batch setups has omitted its use in real-world technical applications.[2]

In this work, we used ultrashort-pulsed LFL to comminute the model nutraceuticals curcumin and cannabidiol (CBD) in an optimized flow-through flat-jet reactor, which allows precise control of the irradiation dose per volume element and results in a drastic reduction in the total number of laser pulses required for size reduction. Our results show quantitative conversion of organic model-MP to the nano- and submicron size range after only one irradiation cycle, enabling continuous operation. H-NMR and HPLC analyses consistently show that chemical degradation is minimal (<< 0.5%) after quantitative LFL of the nutraceutical model substances. Complementarily, this study provides mechanistic insight into the to-date underexplored laser fragmentation processes of organic microparticles.

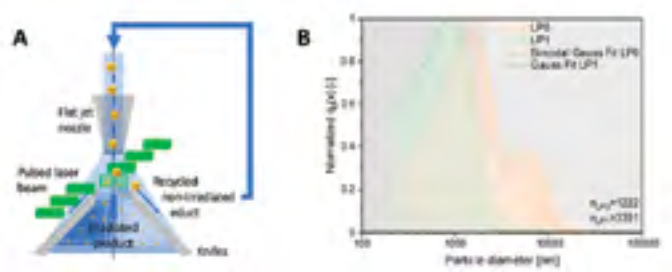

Figure 1. Pulsed laser nutraceutical solubilization: A) Setup of flow-through reactor for LFL and B) Particle size reduction of curcumin after one laser cycle (LP1)

References: [1] R. Müller, C. Jacobs, and O. Kayser, Advanced drug delivery reviews, V. 47, No. 1, pp. 3–19 (2001).

[2] T. Friedenauer, K. Buck, M. Eberwein, A.-L. Bünte, C. Rehbock, S. Barcikowski, Part. Part. Syst. Charact, 2300034 (2023).

Tomato paste edible films in the presence of pectin and carrageenan 216

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ABSTRACT

Edible films from biopolymers are lately receiving great attention as alternatives of plastic packaging due to their biodegradability. Moreover, they can improve the product's life, quality and safety and provide mechanical protection. The presence of antioxidants in their formulation can impart antioxidant properties. Thus, the present work, studied the formation of films with tomato paste (0, 5 and 10% w/w) in the presence of high and low methoxyl pectin as well as ι- and κ-carrageenan, on their own or in mixtures, at a total concentration of 1.0 % w/w. Glycerol was added as a plasticizer. The films were evaluated in terms of their weight, thickness, density, moisture content, turbidity, colour, mechanical properties, water vapor permeability (WVP) and antioxidant activity (AA). Weight varied from 0.48-1.53 g, thickness from 61-143 μm, density from 1.37-2.12 g/cm^3, turbidity from 22-488, WVP from 3-8.47 10^{-8} g mm/h cm^2 Pa whereas moisture content from 19-49%. Maximum force and modulus values ranged from ~7-30 N and ~111-504 kPa, respectively. According to our findings, the presence of tomato paste led to films with lower moisture content and greater weight, thickness, turbidity, strength and WVP. Moreover, the film's weight, thickness, strength and turbidity were greater at the higher tomato paste concentration. The addition of κ-carrageenan to the mixtures was significant for weight, strength and WVP. All films had a red colour due to the presence of tomato paste. AA, attributed to the presence of lycopene, increased with increasing tomato paste concentration. Its values ranged from 1.27-51.92%. Overall, the properties of the films were affected by both the tomato paste concentration and the type of biopolymer used suggesting different biopolymer-tomato paste interactions. The films can serve as a good source of antioxidants and can be used as active packaging improving the self-life of a food product.

Development of hydrogel containing C-phycocyanin from Spirulina for 3D food printing
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ABSTRACT

Spirulina has high protein content, fatty acids, chlorophyll, carotenoids, and phycobiliproteins. Among these compounds, C-phycocyanin (C-PC) is the most prominent natural pigment due to its blue color and antioxidant and anti-inflammatory properties. The objective of this work was to formulate a hydrogel containing agar, xanthan gum, and C-PC to use as a bioink for 3D printing and evaluate its printability, stability, adhesion, and colorimetry parameters in the presence of and protected from light for 7 days. The best conditions for printing were through a 0.8 mm tip, with an extrusion speed of 150 mm/min, printing speed, and internal filling of 75%. There was a decrease in the height of controlled samples of, on average, 23.09% and 14.34% in samples containing C-PC. There was a behavior similar to the expected width and length in controls (5% and 7.89%) and (6.08% and 8.78%) in samples with C-PC. Compared to the loss of height, the width and length underwent smaller changes because the samples presented have 25% space in their internal filling, a determining factor in the collapse of the structure, together with the action of gravity and the loss of water. Regarding colorimetry, the C-PC hydrogels showed negative values for the chromatic coordinate b*, confirming the blue color. The hydrogel exposed to light presented a b* value closer to 0, with a loss of blue color due to the manipulation of C-PC, corroborating the photolability of the compound described in the literature. C-PC was successfully incorporated into the hydrogel. The results will direct the subsequent stages of C-PC bioink application for food products.

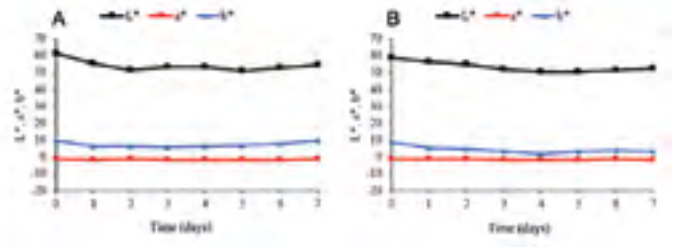

Figure 1. L*a*b* plots versus time for hydrogels under different conditions: control hydrogel (A) and C-PC hydrogel (B)

Acknowledgements: This study was also supported by "Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP", through the grants process nº 2023/00857-0, 2022/06293-9 e 2020/06732-7.

Development of multilayer antimicrobial films for sustainable food packaging 221

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ABSTRACT

People are consuming more fresh fruits and vegetables than ever before. However, the susceptibility of fresh produce to microbial contamination presents great challenges to transport and storage. It can be helped by antimicrobial packaging enriched with essential oils, where the release of essential oils results in loss of antimicrobial activity. To program their release behavior, multilayer films were fabricated by alternatively depositing soy protein isolates (SPI) and low methoxy pectin (LMP) on a substrate, using spray coating, and nano-emulsion droplets containing the active component were incorporated in the primary layer. Carvacrol, one of the main components in essential oils from certain herbs, was chosen to model the release behavior in such system. The surface morphology and 3D structure were imaged via atomic force microscopy (AFM) and multiphoton microscopy. The release profile was characterized by gas chromatography-mass spectrometry (GC-MS). Results revealed the successful formation of the layer-by-layer structure using spray coating, with the release behavior tunable via changing the numbers of deposited layers. This approach could provide a promising alternative to control the release of essential oils in active packaging, and thereby protect fresh produce from microbial damage in an environmentally friendly way.

Food 3D Printing of Personalized Cannabis Edibles: A Focus on Aerated MCT Oil Oleogels 222

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ABSTRACT

In this study, Medium Chain Triglycerides Oil (MCT Oil) oleogel structured by Glycerol Monostearate (GMS) was foamed using a syringe-to-syringe apparatus. This process enables the incorporation of air in a reproducible and accurate manner. Additionally, this technique can be applied even to small volumes of material without the need for using special equipment. MCT oil was selected as the most used vegetable oil for hosting cannabinoids, due to the higher solubility of cannabinoids in MCT oil. The resulting foams were evaluated based on the overrun (foamability) and their oil binding capacity. The evaluation of the foams was complemented by rheological studies, Confocal Laser Scanning Microscopy (CLSM), and color evaluation studies. The optimum formulation was evaluated for its suitability to be accurately printed into edible dosage forms containing Active Pharmaceutical Ingredients (APIs) like cannabinoids. The present study is part of a project entitled "Food 3D Printing of Personalized Cannabis Edibles-Bak3D".

Acknowledgements: The research project was supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the "3rd Call for H.F.R.I. Research Projects to Support Post-Doctoral Researchers" (Project Number:7591).

Gum arabic -pectin powders loaded with eggplant peels' extract 238

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ABSTRACT

As most of the by-products and the waste of the food industry are rich in bioactive compounds, there is an increasing interest for their exploitation. Among the by-products, eggplant peels are rich in antioxidants like anthocyanins. Anthocyanins are phenolic compounds which also are responsible for the colour of plants. In the present work, anthocyanins were isolated from eggplant peels and the extract was incorporated in biopolymer powders formed by oven drying using Gum Arabic (GA) alone or in mixtures with high (HMP) and low methoxyl (LMP) pectins. Several physicochemical properties of the powders were studied like bulk, tapped and particle densities and porosity, flowability and cohesiveness, solubility, moisture content, colour and total phenolics content. Bulk, tapped and particle densities and porosity varied from 0.67-0.75 g/cm^3, 0.70-0.82 g/cm^3, 1.18-2.51 g/cm^3 and 40.7-65.6 %, respectively. The incorporation of pectins led to powders with increased porosity, bulk, tapped and particle densities. All powders had very good flowability (i.e. Carr Index: ~3-8) and low cohesiveness (i.e. Hausner ratio ~1.06). Their moisture content and solubility were ~0.4% and ~63%, respectively. Regarding colour, brightness varied from ~24 to ~42, with the GA-LMP powder being the least bright. Redness was close to +30 for all samples as expected due to the presence of anthocyanins. The powders shared statistically the same phenolics content (~0.109 mg GAE/0.5 mL) which was lower than the phenolic content of the initial extract (~0.243 mg GAE/0.5 mL). Overall, the incorporation of pectins was significant for most of the measured properties. As the powders retained about 45% of the phenolics content of the extract it looks that the formation of the powders of the present study can be a first step in the modulation of anthocyanin loaded powders for future use as encapsulating, antioxidant and colour agents in food matrices.

4D Printing for Morphing Food: Bridging Shape Morphing Behaviors from Non-Food to Food-grade Materials 245

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ABSTRACT

The acceptability of food by consumers significantly hinges on its shape, rheological characteristics, and packaging requirements. Shape morphing represents a novel technique to enhance consumer acceptance of custom-designed 4D foods while concurrently reducing food packaging waste and increasing food sustainability. However, the current methods for controlling food shape morphing are limited, and the information is fragmented. This study aimed at a comparative investigation of deformable materials fashioned using a double-layer methodology, extending formulations from conventional non-food materials (e.g., plastics and paper) to food-based substrates (e.g., protein and cellulose). We integrated 4D printing concepts with rheological analysis (e.g. rheometer and texture analyzer), focusing on the double-layer approach (zein-gelatin or cellulose-gelatin bilayers) with designed fundamental geometries. The results show that the deformation responses of food and non-food double-layer constructs are based on the level of swelling properties between the active layer and the non-active layer. The rate of shape change depends on the difference in swelling rate between the two layers of materials in response to the stimulus, and the maximum value of the material's mechanical properties and intensity of the stimuli determine the extent of deformation. This approach is extended from non-food materials to food-based deformable materials, unveiling a clear avenue for designing and applications of morphing food.

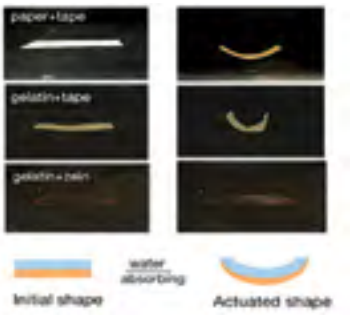

Fig.1 Shape morphing of different double-layer combinations.

Development of technologies for producing feed based on keratin hydrolysates from animal waste 287

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ABSTRACT

In recent years, 25-37 tons of wool and 7.5 million hides have been produced annually in the Republic of Kazakhstan, which are considered to be huge keratin resources. About 43% of wool is not processed and is lost, as well as removed by burning, which not only wastes keratin resources but also causes health-threatening diseases and leads to serious environmental problems in the environment. Thus, the study of the role, properties and use of keratin raw materials of animal origin determines its relevance for saving resources and reducing environmental pollution. The purpose of the research work is to develop environmentally friendly technologies for producing bioactive protein hydrolysate with high nutritional and functional value for animal feeding based on sheep waste to improve the productivity and quality of livestock products.

Developing the new hydrolyzed materials and optimizing processing conditions for their fabrication requires a thorough understanding of the interplay between the physicochemical properties of the material, process dynamics, and reaction kinetics as a function of the feedstock composition. To determine significant factors affecting the stability of keratin hydrolysates and their functionality as broad-spectrum dietary supplements for feed purposes, advanced experimental methods were used, such as infrared spectroscopy, electron microscopy, elemental and biochemical analyses to identify conformational changes in the structure of keratin proteins.

The study focused on developing technology for producing bioactive protein hydrolysates from underutilized renewable sources, specifically targeting livestock byproducts and waste, such as sheep wool. The study performed some tasks: a comprehensive analysis of sheep wool waste generated during the breeding process; to development of a suitable method, testing its effectiveness and optimizing the process of bioactive components; and to development of a multifunctional delivery system. This system is hydrolyzed protein-based and encapsulates important functional components such as vitamins, micronutrients, and probiotics for effective integration into animal feed.

Innovative Microfibers Carotenoid Encapsulation: Electrospun Polymeric Composites for Controlled Release for Food Applications 295

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ABSTRACT

Natural pigment encapsulation in polymeric matrices as a delivery system controlled is a blooming area of research and arouses interest in the food industry to use micro- and nanotechnology strategies. An excellent tool for forming micro- and nanofibers with carotenoid encapsulation is electrospinning. Carotenoid encapsulation, a lipophilic pigment, shows efficacy in improving and increasing chemical stability and bioavailability by modulating solubility, interfacial properties, and release kinetics in the carrier system. In this study, polymeric composites combining solutions of zein, polyethylene oxide (PEO), and pectin with carotenoid incorporation subjected to electrospinning were produced and microscopically characterized. The applied voltage was 20 kV with a feed rate of 1800 (µL/h), a tip-collector distance of 10 cm, and a 0.6 mm diameter steel needle. Carotenoids extracted with acetone and the ionic liquid [BMIM][BF4] from pequi, a Brazilian biodiversity fruit, were incorporated (80µg/mL). Two formulations were tested (1: zein, PEO, and carotenoids; 2: zein, PEO, pectin, and carotenoids), and carotenoids were successfully incorporated. These two formulations form microfibers (µm) with uniform shape and diameter definitions (Figure 1). Comparing the diameters obtained, standard formulation 1 with pequi carotenoids incorporated presented significantly smaller diameters ($p < 0.05$) than standard formulation 2 with pequi carotenoids incorporated. It is known that pectin biopolymer presents difficulties for electrospinning due to its polyelectrolytic nature, despite obtaining fibers with high water resistance. Thus, it is observed that the electrospun fibers composed of zein, PEO, pectin, and carotenoids extracted with the ionic liquid [BMIM][BF4] showed greater diameter and size variation of the electrospun fibers. These results represent a crucial step in the carotenoid application in food systems as pigments, establishing a basis for further research on the incorporation of polymeric composites into foodstuff.

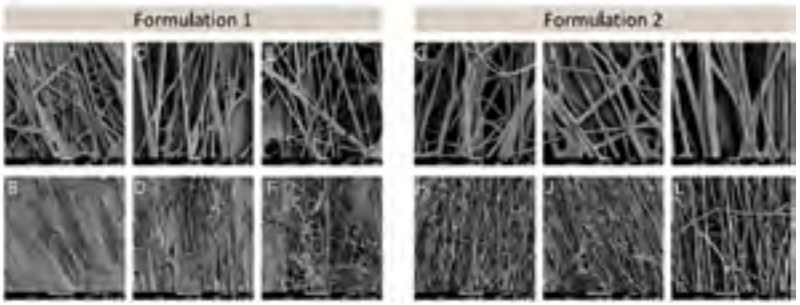

Figure 1. Field emission scanning electron microscopy. From left to right: formulation 1. (A) and (B) without carotenoids; (C) and (D) carotenoids extracted with acetone; (E) and (F) carotenoids extracted with [BMIM][BF4]; formulation 2. (G) and (H) without carotenoids; (I) and (J) carotenoids extracted with acetone; (K) and (L) carotenoids extracted with [BMIM][BF4], respectively.

Acknowledgments: This work was supported by "Fundação de Amparo a Pesquisa do Estado de São Paulo - FAPESP" through fellowship (2021/00596-7) and grant (2021/02692-3).

Citrus fiber-based edible food films 313

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ABSTRACT

Global food packaging market is expected to expand at a compound annual growth rate around 5% until 2028. [1] However, the materials commonly used in packaging industry are derived fossil-based plastics, leading to a rising concern about their disposal and the resulting environmental hazard. In this context, social and scientific interest has put the attention on replacing the existing materials with more sustainable alternatives with the goal of reducing the overall production of plastic waste. Therefore, biopolymers are nowadays widely considered as a promising options thanks to their biodegradability and potential in packaging applications.

Edible food films based on citrus fiber were casted from aqueous solution. The formulation was adjusted by blending with pectin and varying the amount of plasticizer added into the system.

Film thickness and transparency were evaluated. The effect of different dispersing conditions was investigated. Later, the film properties were tested under different environmental conditions which were simulated by the variation of relative humidity and temperature. Barrier properties were investigated measuring water vapor and oxygen permeability. Finally, dynamic mechanical properties were studied.

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Acknowledgements: A grant from the Innovation Fund Denmark is gratefully acknowledged. The authors acknowledge CP Kelco for its contribution.

Role of enzymatic modification of Pickering particles – a strategy to induce demulsification 324

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ABSTRACT

In recent years, Pickering emulsions have gained significant research interest in the food and pharmaceutical industries, due to their ability to provide ultrastability to emulsion systems. However, the process of demulsification, critical for releasing active ingredients on demand, has received limited attention in the existing literature. The aim of this study was to understand the factors influencing demulsification of Pickering emulsions stabilized by whey protein microgel particles (WPM), with a particular focus on evaluating the influence of trypsin on the WPM. The capability of trypsin to induce alterations in WPM (12 wt% protein) was monitored at 30-minute intervals over a duration of 2 hours, under pH 7.0 conditions and characterization was conducted using dynamic light scattering, drop shape tensiometry and rheological analyses. Results showed that the exposure to trypsin led to a notable decrease in WPM particle size by 59%, a similar trend was observed in reducing both interfacial tension and viscosity. This behavior exhibits promise as it leads to the thinning of the interfacial film by reducing the particle size and could potentially contribute to the demulsification of Pickering emulsions when WPM is used as a Pickering stabilizer.

Future studies are looking at microstructure of these WPM particles at the oil-water interface when they undergo enzymatic hydrolysis.

Acknowledgements: This research is supported by the Engineering and Physical Sciences Research Council (EPSRC) CDT Molecules to Product grant EP/S022473/1

Enrichment of an Atlantic bonito burger with chickpea, Spirulina and Fucus vesiculosus: antioxidant activity, physicochemical and texture properties with different hydrocolloids 330

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ABSTRACT

The European Market Observatory for Fisheries and Aquaculture Products report reveals that fish consumption in 2021 increased to 2.5 times than the European average. It is crucial to develop alternatives to improve the nutritional and organoleptic conditions of fish, and to valorise the ecological impact of dietary choices, which are decisive for the sustainability of marine environments.

The Atlantic bonito is an abundant and undervalued fish, compared to other species, it stands out for its favourable aspects, such as its composition rich in lipid and protein nutrients and a characteristic taste.

The objective of this work was to develop and optimize a formulation of a fish burger based on Atlantic bonito with the addition of plant-based ingredients such as chickpea and algae, and hydrocolloids to the formulation.

The effect of different hydrocolloids, xanthan (0%, 1% and 3%), carrageenan (0%, 2% and 4%), algae, Spirulina (0.5%, 1% and 2%), and Fucus vesiculosus (1%, 2% and 3%) on physicochemical (moisture, pH, fibre, lipid, chloride, protein and ash content), texture properties, phenolic compounds and antioxidant activity (DPPH, ABTS) of the Atlantic bonito burger were assessed by an experimental design based on Taguchi method.

Results showed that the formulation with 2%spirulina, 3%Fucus vesiculosus, 0%xanthan and 4%carrageenan, increased 1.5-fold the fibre content, 2.8-fold the protein content, 1.2- fold the antioxidant activity (ABTS) and 3.4-fold the total phenolic content when compared to the control. On the contrary, no significant differences were found on moisture and antioxidant content (DPPH). Regarding the texture results, the higher algae composition the higher burger hardness. Concerning burger cohesivity, adhesiveness, gumminess and harness results showed no significant effect regardless of hydrocolloids type or concentration.

From this work it was concluded that the addition of algae, like Spirulina and Fucus vesiculosus, improved the nutritional and antioxidant activity of the Atlantic bonito burger.

Acknowledgements: The authors thank the Blue Project, Bioeconomy, People, Sustainability, Health (PT-INNOVATION-0105). Iceland Liechtenstein Norway EEA grants. Blue Growth Programme. Call2 – Business, Development, Innovation and SMEs.

A green approach for the development of novel chitosan hydrogels for food applications 334

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ABSTRACT

Hydrogels are 3D hydrophilic polymeric networks with a porous structure which imparts remarkable water retention capabilities. In the last few years, there is an increasing interest in these materials due to their high biocompatibility, low toxicity, easy preparation, and tuneable mechanical properties, thus finding application in various fields, including cosmetics, pharmaceutical and food industries. Specifically in the food industry, hydrogels can be used as carriers for the controlled release of additives and flavors as well as food packaging materials, ensuring food safety, and prolonging the products' shelf life.

Chitosan is a unique natural polysaccharide, derived through the deacetylation of chitin, with well-known antioxidant, lipid-lowering and antimicrobial activities. Chitosan is widely used for the preparation of hydrogels using the ionic gelation method due to its cationic nature. Natural Deep Eutectic Solvents (NADES) are a class of solvents that are composed of

naturally occurring components such as sugars, organic acids, amino acids, and other small molecules, which at specific ratios form eutectic mixtures, with a melting point significantly lower than its individual components.

In the present work, a greener approach towards the formation of hydrogels using different molecular weights of chitosan and NADES as cross-linking agents is presented. The swelling ability of the prepared hydrogels was measured by immersing the hydrogels in appropriate buffer solutions simulating different environments. It is noteworthy that all the prepared hydrogels exhibited significant swelling properties, ranging between 200-600%. One of the best swelling results (530%) were obtained when chitosan of low molecular weight was used, along with a NADES comprised of choline chloride and lactic acid as a cross-linker.

Exploring chitosan-whey protein concentrate-candelilla wax emulsions performance as a coating for kraft paper 335

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ABSTRACT

Paper surface modifications, such as the application of waxes and multi-layer lamination films, are used in the packaging market. However, they pose an environmental problem related to the recycling and recovery of materials. The food packaging industry can benefit from the use of bio-based materials to reduce these technological downsides. In this study, a chitosan (CH), whey protein concentrate (WPC) and candelilla wax (CW) emulsion coatings were developed and applied on the surface of kraft paper (40 and 80 g/m^2) in order to improve its properties. Different CH-WPC-CW emulsion coating formulations were produce using a 2^3 central composite rotational design (CCRD) and characterized for rheological properties and emulsions' size, ζ-potential and polydispersity index (PDI). Moreover, barrier (to water vapor and oxygen), mechanical (tensile strength, TS; elongation at break, EB; Young modulus, YM), surface (contact angle measurements) and structural properties of kraft paper coated with CH-WPC-CW emulsion formulations were assessed. Results showed that CH concentrations can influence negatively the emulsions' stability after 7 days of storage. In addition, through the rheological characterization, solutions presenting higher viscosities or low pseudoplasticity were rejected as paper coatings. After applying the optimized formulations to the paper surface, it was observed that coatings significantly increase paper barrier efficiency to water vapor and oxygen, as well as TS, when compared with uncoated kraft paper. To conclude, it was possible to observe that the optimized bio-based emulsion coatings presented promising properties as an alternative to the synthetic coatings already applied to kraft paper.

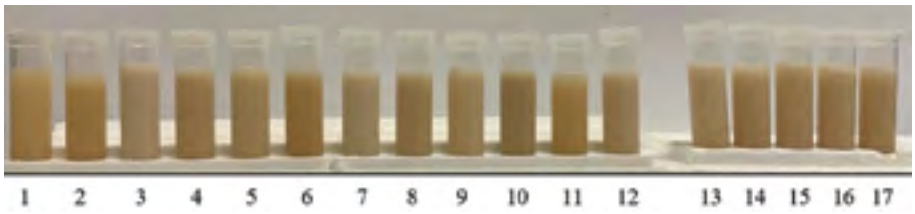

Figure 1. Photographs of CH-WPC-CW emulsion coating formulations developed according to a CCRD (2^3) to be applied on the kraft paper surface.

Acknowledgements: This study was supported by Recovery and Resilience Plan (RRP) and IAPMEI - Agência para a Competitividade e Inovação, IP under the scope of "FF2F - From Fossil to Forest - Sustainable packaging and products to replace fossil plastic" project (02-C05-i01.02-2022.PC644920945-00000036). This study was also supported by the Portuguese Foundation for Science and Technology (FCT) under the scope of the strategic funding of UIDB/04469/2020 unit, and by LABBELS – Associate Laboratory in Biotechnology, Bioengineering and Microelectromechanical Systems, LA/P/0029/2020. J. T. Martins acknowledges FCT for her Assistant Research contract obtained under the scope of Scientific Stimulus Employment (doi: 10.54499/2022.00788.CEECIND/CP1718/CT0024).

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P2. NEW METHODS AND NEW INSIGHTS IN FOOD COLLOIDAL SYSTEMS

The road towards animal-free cheese from recombinant casein: Novel preparation processes to engineer artificial casein micelles with tailored properties 4

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ABSTRACT

The production of high-quality animal-free cheese may become feasible due to advances in the recombinant synthesis of milk proteins through precision fermentation. To allow the production of dairy alternatives with these novel proteins, it is essential to study and explore innovative pathways for the self-assembly of caseins into the micellar structures found in milk and link the properties of these micelles to the formation of curds upon rennet-induced coagulation. In our research, we found that casein micelle formation is essentially a calcium phosphate supersaturation process, upon which casein stabilises the incipient calcium phosphate nanoclusters to give rise to the supramolecular casein micelle structure. Based on this principle, we developed novel processes to form artificial casein micelles through vacuum evaporation, forward osmosis, and reverse osmosis. Artificial casein micelles formed with these novel processes displayed superior coagulation properties, such as an increased curd firming rate. Furthermore, we found that the properties of the micelles are dependent on the conditions of the preparation process. For example, the level of micellar calcium phosphate could be controlled by adjusting the preparation temperature and the preparation rate influenced the size of the micelles (Figure 1). In turn, this allowed us to study the effect of these micelle properties on their coagulation behaviour. Although the standard micelle formation process yielded micelles similar to bovine casein micelles regarding rennet coagulation behaviour and curd melting, micelles formed under different conditions displayed significant differences. Our research thus demonstrates the ability to tailor the preparation process to engineer artificial casein micelles with desired properties based on the target functionality. Furthermore, the new micelle formation processes give insight into the principles of casein micelle formation and allow for the resource-efficient industrial production of artificial casein micelles. Therefore, our research paves the way for the future production of animal-free cheese from recombinant casein.

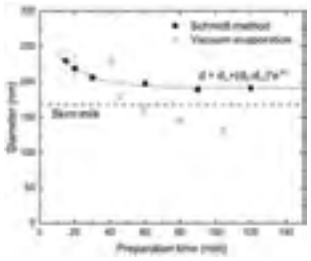

Figure 1. Diameter of artificial casein micelles prepared with the method of [1] or vacuum evaporation at different preparation times.

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Exploring the Potential of Plant Proteins in Food: Insights from FoodProteinsDB 32

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ABSTRACT

Animal- and plant-based proteins are present in a wide variety of raw and processed foods. They play an important role in determining the nutritional properties and the structure/texture of food [1]. One of the current challenges is to replace, at least partly, animal-derived proteins with more sustainable alternatives, like proteins from plants, insects, and/or algae [2]. This requires a comprehensive understanding of the effect of food processing, like temperature, shear, on the structure and dynamics of proteins assembly. We have initiated an *in-silico* exploratory study, within food proteins, to uncover potential drivers of their functional properties, such as solubility and aggregation. We built a reference database of food proteins, called FoodProteinsDB, that comprises protein sequences and their predicted physicochemical, biochemical, spectroscopic, and structural properties. Statistical analyses were carried out on the data to identify the main explanatory variables of the observed differences between the major classes of proteins and, interpret the observed differences/generics. One significant finding, from our initial analysis, was that amino-acid sequences of plant storage proteins are predicted to be more disordered than globular animal proteins, such as whey or egg proteins. Looking in more details in plant protein sequences reveals that most of them contain low complexity regions. Such domains comprised polar and/or charged amino acids which are mostly predicted disordered. We question the role of such sequence in the self-assembly of plant storage proteins in seeds and during food processes.

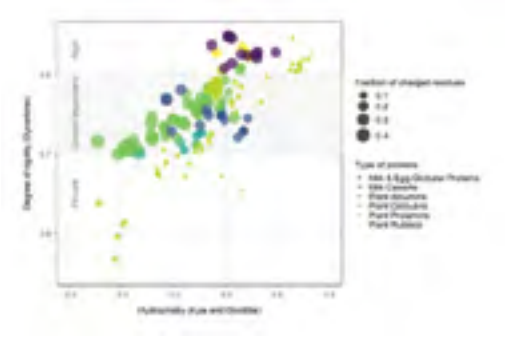

Figure 1: Predictions of backbone dynamics and hydropathy index of plant and animal storage proteins based on their amino-acid sequence. Data include rapeseed, pea, soy, wheat, sorghum, barley and maize proteins in green and milk and egg proteins in red. Degree of disorder was predicted using DynaMine application and the hydropathy index using ExPasy server based on Kyte & Doolittle method.

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Heat induced aggregation and gelation of casein micelles. Influence of citrate and orthophosphate 35

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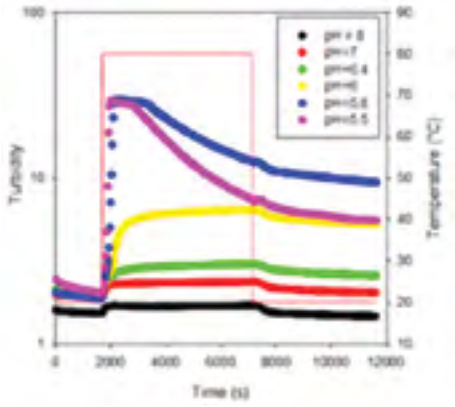
ABSTRACT

Casein is the most abundant milk protein forming spherical colloidal complexes called casein micelles. Here we report on aggregation and gelation of casein micelles in aqueous suspension during heating at different temperatures up to 80°C. It was found that the turbidity increases with time during heating stabilizing at a value that increases with increasing temperature. This effect is only partially reversed by cooling and is more important at lower pH, becoming strong below pH 6.4. Small aggregates are formed at low concentration (<5g/L), whereas at higher concentrations, large aggregates precipitate as flocks or a gel is formed.

The effect of adding citrate or orthophosphate on heat induced aggregation and gelation of casein micelles was studied at pH 5.8 both with turbidimetry and rheology. It was found that heat induced aggregation was inhibited at low casein concentration by the addition of citrate, whereas the effect of adding the same amount of orthophosphate was much weaker. At a high casein concentration of 14 wt%, a dramatic increase of the viscosity was observed at room temperature above a critical concentration of citrate or orthophosphate. During heating two types of gelation were observed at this high casein concentration. Pure micelle suspensions formed rapidly homogeneous gels above a critical temperature close to 40°C. The critical temperature increased with increasing amount of added citrate or orthophosphate and this type of gelation was no longer observed below 90°C when the latter exceeded 14 g/L. At higher concentrations of citrate or orthophosphate macroscopically heterogeneous gels were formed that could not be characterized by rheology. However, applying strong shear led to the formation of homogeneous very viscous suspensions.



Normal stress rheology (NSR) is a powerful tool to probe complex food structures 37

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ABSTRACT

When subjected to shear, complex materials exhibit normal stresses perpendicular to the shear. Although shear-induced normal stresses have been studied extensively for polymers [1], it is often ignored for other soft materials including foods. While shear rheology is widely used to investigate food hydrocolloids, normal stress rheology (NSR) is completely new in food science. It is known that the normal force response of foods contributes to the mouthfeel, therefore, understanding the normal response behavior of edible materials is crucial to understanding the sensory perception better. Besides that, there is a current lack of quantitative methods to compare highly anisotropic systems such as meats and fibrous plant-based analogues, where NSR can be a solution. Here we introduce several examples that normal stress rheology can be used to investigate the nonlinear response of complex food systems from highly anisotropic soft solids (meat and fibrous meat analogs) to structured multiphase systems such as liquid foams, emulsions and slurries. Shear-induced normal stress rheology reveals differences in these highly anisotropic systems that can not be clearly observed based on the results of conventional shear rheology. This approach provides a deeper understanding of the structure-function relation. The results of normal stress rheology show that fiber orientation, fiber strength and fiber micro rearrangement under deformation govern the normal response [2]. The second example is the slurries with complex shear rheology that is often ill-understood. NSR can explain the influence of the particle size and flow of the medium in the complex rheology of slurries and suspensions by disentangling the contribution of the solid matrix and the liquid stress and characteristic flow time scale that determines the final normal stress behavior [3]. In addition, NSR provides very important information about the onset of yielding and flow of foams and emulsions [4]. Finally understanding the NSR of food materials is essential to predict their die-swell after extrusion with diverse applications from food 3D printing to food processing.

Figure 1. When subjected to shear, materials exhibit normal stresses perpendicular to the shear, which can give lots of information about the nonlinear rheological properties of food materials.

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Rational design of food processing methods with aid of neutron scattering 62

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ABSTRACT

Sustainable food production is one of the priorities to prevent further climate change. This requires new processing techniques that with sustainable ingredients yield high quality food. When processing raw materials to final consumer food products, their structures change at length scales from nano-, via meso- to macroscopic sizes. To rationally design food processing routes, insight in these hierarchical structures under dynamic conditions, is a prerequisite. Systems of practical relevance to the food industry are often hard to investigate non-invasively. This is caused by the fact that most food materials are opaque and soft materials. Neutrons make it possible to see the bulk of food materials.

Several examples will be discussed where the spin-echo small-angle neutron scattering (SESANS)technique is used to determine the food structures [1 of: colloidal systems, gels and fibres.

Figure 1. Spin-echo small-angle neutron scattering instrument at Delft University of Technology

[1] *Spin-echo small-angle neutron scattering for multiscale structure analysis of food materials,* W.G. Bouwman, Food Structure **30** 100235 (2021), https://doi.org/10.1016/j.foostr.2021.100235

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Atomic force microscopy of lignin-stabilized Pickering emulsions at the nanoscale 67

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ABSTRACT

Emulsions are ubiquitous in nature, and they are extensively used in life science and chemical industries. Making them more sustainable would bring a major green shift due to large production volumes. An important change is to replace surfactant molecules by biomaterial-based nanoparticles as emulsion stabilizers. With appropriately chosen materials, Pickering emulsions (PE) are safer, stabler, and more environmentally friendly than their surfactant-stabilized counterparts. A major bottleneck for advancing the technology is the lack of good analytical methods to visualize nanoscaled emulsions.[1] Current analytical techniques have various drawbacks, e.g., their resolution is satisfactory only at micrometer scale, they cannot utilize real-world samples, or the methods are complex and require heavy altering of the samples by freezing or drying. We present a versatile and easy analysis method. Samples were collected from different parts of bulk emulsions. The droplets and nanoparticles in their surfaces were analyzed with wet Atomic Force Microscopy (AFM). Mechanical data was mapped on the 3D topographic data for clear visualization of the interfaces. Nanoparticle movements and coalescence events of submicron droplets were inflicted and recorded *in situ*. Special focus was paid to lignin nanoparticles (LNP) as stabilizing material because it is biodegradable and fossil-free material with great abundance. LNPs were compared to silica nanoparticles and their behavior is discussed, e.g., how the soft LNPs can be reshaped in the liquid-liquid interface by the AFM.

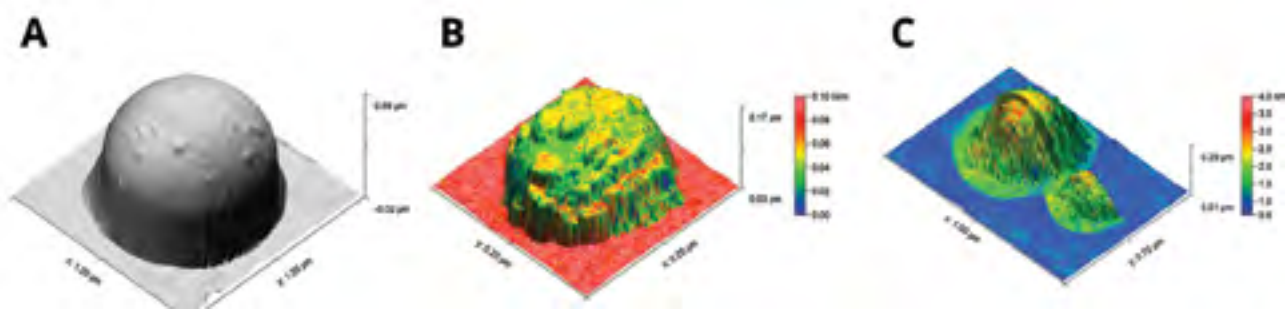

Figure 1. AFM micrographs of submicron o/w droplets. A) Topographical rendering of AFM data with small nanoparticles on an oil droplet. B) Slope of the force-distance curve overlaid on topographic data of a lignin-stabilized droplet. C) Adhesion overlay on topographic data showcasing the coalescence of two droplets at alternative imaging conditions.

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Pulsed electric field altered the structural and physicochemical properties of casein micelles 98

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ABSTRACT

Pulsed electric field (PEF), recognized as an environmentally friendly processing technology, has garnered increasing attention for its potential to align with sustainable development goals. In this research, we explored the impact of various electric field strengths (EFS, ranging from 0 to 30 kV/cm) on the characteristics and structures of casein micelles (CSMs) [1]. Our investigation revealed that, at lower EFS (10 kV/cm), CSM particle sizes increased, whereas higher EFS (30 kV/cm) led to a reduction in particle size. Additionally, the absolute ζ-potential at 30 kV/cm increased from -26.6 mV in native CSMs to -29.5 mV.

Furthermore, our analysis demonstrated alterations in surface hydrophobicity induced by PEF treatment. At EFS of 10 kV/cm, surface hydrophobicity exhibited a slight increase, but it decreased at EFS levels exceeding 10 kV/cm. PEF treatment also resulted in improved protein solubility, rising from 84.9% in native CSMs to 87.1% at an EFS of 10 kV/cm. The emission fluorescence spectrum of CSMs was found to be intensified by PEF treatment at low EFS (10 kV/cm), while higher EFS levels reduced fluorescence intensity compared to native CSMs. Moreover, FTIR results and the analysis of the Amide I region (1600-1700 cm^{-1}) indicated that PEF-treated CSMs experienced a decrease in α-helix content and an increase in β-sheet content. Raman spectra further confirmed that PEF treatment at levels exceeding 10 kV/cm caused tyrosine (Tyr) residues to be sequestered in a hydrophobic environment. Additionally, it was observed that PEF treatment primarily induced modifications in the disulphide linkages of CSMs.

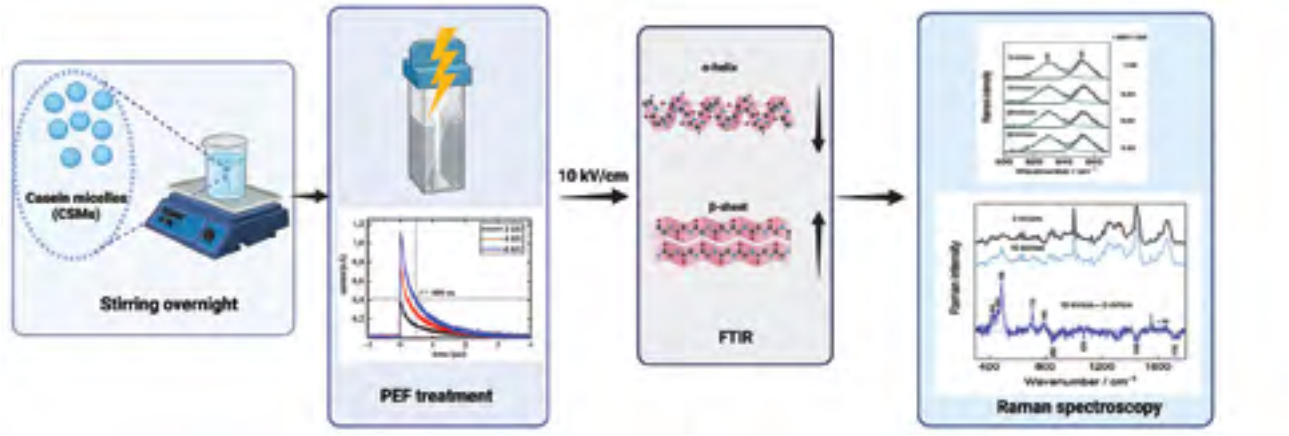

Figure 1. Graphical abstract representing a summary of the study.

References: [1] Taha, A., Casanova, F., Talaikis, M., Stankevič, V., Žurauskienė, N., Šimonis, P., ... & Stirkė, A. (2023). Effects of Pulsed Electric Field on the Physicochemical and Structural Properties of Micellar Casein. Polymers, 15(15), 3311.

Pulsed laser diffusion enhancement in liquids for cold extraction of coffee powder 114

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ABSTRACT

The extraction of flavorings from solids is highly relevant in the food industry. In general, the extraction process is not only associated with an intensification of flavor and taste, but also brings numerous nutritional (health-related effect e.g. antioxidants) improvements. Therefore, there is a major interest in the technological advancement of water-based extraction processes that produce highly aromatic extracts of these sensitive natural products, accompanied by minimum losses of volatile compounds. Laser processing in liquids of organic microparticles has been frequently addressed in the literature, though mostly focused on size reduction and solubilization of drug particles [1]. However, whether or to what extent food extraction processes are affected by laser irradiation in water, is underexplored.

In this pioneering work we show that picosecond laser irradiation at comparable fluence (<20 mJ/cm^2) can accelerate the cold extraction time of coffee from typically 12 hours to 3 minutes. Initial results show that laser-extracted coffee has a similar aroma profile with identical amounts of alkaloids as cold-brewed without the formation of degradation products. 30 mg of caffeine per 100 mg of water could be extracted by the laser process within 3 min, which agrees with the conventional amounts in hot and cold brewed coffee. Due to the short extraction time of the laser-based method, a 300 times more effective caffeine extraction could be achieved compared to cold brew methods and a two to three times higher extraction efficiency compared to hot brewed coffee was found. Furthermore, laser brewed coffee was shown to have other positive flavor attributes, like a significantly reduced acidity in comparison to the most frequently drunk hot-brew coffee [2]. This underexplored laser processing method of organic particles termed Pulsed Laser Diffusion Enhancement in Liquids (PUDEL) could pave the way towards laser extraction as a new method in the food industry.

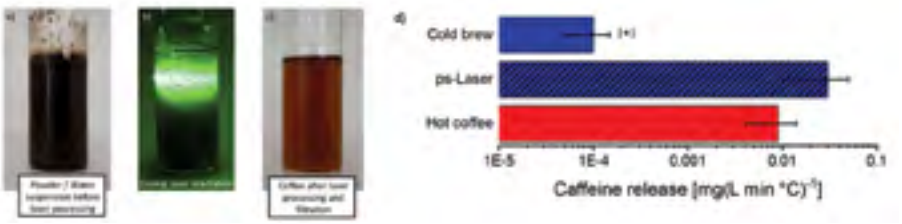

Figure 1. Pulsed laser cold extraction of coffee; a) coffee particle suspension in water; b) ps-laser irradiation of the suspension; c) final coffee extract after 3 min irradiation and subsequent filtration and d) caffeine release of differently brewed coffee types [2]

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In Situ Analysis of Structural Heterogeneities in Multi-phase Colloidal Systems Using Microfluidics, Confocal Raman Microscopy, and FT-IR Imaging Technologies 118

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ABSTRACT

The structure and function of food products are strongly connected to the interactions between their components and the dynamics at both molecular and supramolecular levels. Many foods are complex systems consisting of proteins, polysaccharides, and lipids. They may exhibit structural heterogeneities at the micro- and meso-length scale, with important consequences to the bulk properties. A better understanding of these heterogeneities at spatial resolution can provide essential information about the relation between composition, structure and function and can give insights into complex systems' dynamic and synergistic or antagonistic interactions.

Our research uses advanced microfluidics to create and manipulate colloidal systems by generating initially monodispersed oil droplets with different interface compositions. We employ imaging techniques like Confocal Raman Microscopy and Imaging and FT-IR Imaging, to locate and quantify proteins and polysaccharides in complex structures, to gain insights into oil-water interface composition and dynamics, and to evaluate the effect of the interface on, for instance, lipid domains crystallisation dynamics, *in situ* and in spatial resolution.

We will demonstrate how these two complementary techniques can be employed to better understand structure formation in complex food matrices. By gradually building up systems complexity and performing single droplet analysis, it is now possible to obtain new knowledge on structure formation, performing accurate analysis in spatial resolution. We will also illustrate the potential of the combination of Spectroscopic Imaging and Microfluidics as tools for *in situ* complex systems analysis (Figure 1) and discuss the critical steps that are necessary to ensure robust data analysis and interpretation.

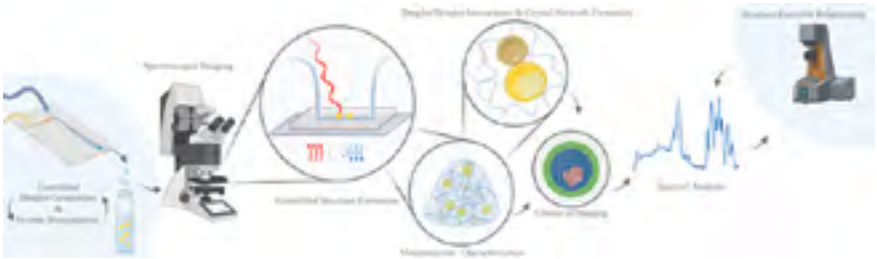

Figure 1: Overview of the methodological approach for *in situ* analysis and characterization of a polymer network containing partially crystallized oil droplets.

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Investigation of aqueous foam from pea-based albumins using small-angle neutron scattering 121

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ABSTRACT

Aqueous foams are important in creating appealing structures in food, but appealing foams with plant-derived proteins are not yet well developed. Studies on the foaming properties of plant proteins are needed. Albumins, present in the side stream extracts of plant protein have shown promise as functional foaming ingredients. This study investigates for the first time the foaming properties of pea albumins, evaluating them in native and aggregated states. We report the simultaneous time-resolved investigation of foams by small-angle neutron scattering (SANS), together with bubbles imaging, from the nanometer to the millimeter scale. Liquid foams were stabilized by pea albumins treated with different pH (3, 4.5, and 8) and evaluated before and after heating at 90 °C for 1 and 5 min the solutions. The SANS scattering intensity was modeled to quantitatively assess foam properties such as liquid fraction, specific surface area of the Plateau borders and inter-bubble films, and thin film thickness. These parameters were related to the liquid fraction and bubble sizes obtained from image analysis. Results demonstrated that film thickness was the highest for albumins pH 4.5, and at pH 8 the foams had the lowest specific surface area. The liquid fraction did not show significant differences among the different pH during aging time (~80 min). Heat treatment led to the increase of the specific surface area and decrease of the film thickness, especially at pH 4.5. This work will show how with this multiscale approach it is possible to understand the underlying foam destabilization mechanisms of albumins and how using advanced physical techniques in relevant environments it is possible to develop the necessary understanding to design more sustainable food foams with appealing physical properties and stability.

Use of κ-carrageenan/chitosan-based coatings containing completely or partially deodorized yellow or Oriental mustard extracts to control Salmonella enterica and spoilage bacteria on fresh chicken breasts 133

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ABSTRACT

Mustard powder has high contents of glucosinolates including sinalbin in yellow mustard and sinigrin in brown or Oriental mustard. These inactive compounds could be degraded using endogenous plant myrosinase or bacterial myrosinase-like activity to produce antimicrobial isothiocyanates (ρ-hydroxybenzyl isothiocyanate from sinalbin or allyl isothiocyanate from sinigrin). The objective of this study was to use the edible 0.2% (w/v) κ-carrageenan/2% (w/v) chitosan-based coatings containing completely or partially deodorized (heat treated, plant myrosinase deactivated) yellow or Oriental mustard extracts to eliminate *Salmonella enterica* and spoilage bacteria on fresh chicken breasts. The *S. enterica*-inoculated pieces of chicken breast fillets (20 g) were dipped in deodorized yellow (100 and 250 mg/ml) or Oriental (250 mg/ml) mustard extracts were added separately alone (completely deodorized) or with 0.25% hot yellow mustard powder (partially deodorized) into κ-carrageenan/chitosan-based coatings. The coated chicken breast fillets were placed into plastic bags that were sealed under vacuum and stored at 4 °C for 21 d. *S. enterica* were not detected on breast fillets that were treated with κ-carrageenan/chitosan-based coatings containing 250 mg/ml partially deodorized yellow mustard extract after 10 d. Coatings containing partially deodorized oriental (250 mg/ml) or yellow (100 mg/ml) mustard extracts reduced numbers of *S. enterica* on breast fillets by 1.7 and 3.2 log CFU/g; respectively, by 21 d. κ-Carrageenan/chitosan-based coatings containing 250 mg/ml completely deodorized yellow or Oriental mustard extracts reduced the *S. enterica* numbers by 1.5 log after 21 d. Partially deodorized mustard extracts were also more inhibitory against spoilage bacteria (aerobic plate count and lactic acid bacteria) than completely deodorized mustard extracts. k-Carrageenan/chitosan coatings containing either partially or completely yellow or Oriental mustard extracts have a potential to reduce *S. enterica* and spoilage bacteria numbers on raw chicken.

Formation and properties of iron-based colloidal systems in the presence of diacid acidity regulators 138

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ABSTRACT

Minerals such as iron are critical components of nutrition. The appropriate intake of these dietary metals is vital for maintaining a healthy life as nutritional deficiencies can lead to a wide variety of maladies, developmental issues, and even mortality.[1] Despite the importance of ensuring an adequate intake of these micronutrients, mineral deficiency remains a global problem. For example, approximately 60% of all cases of anemia, which affects 30% of reproductive-age women and 40% of young children around the world, are the result of iron deficiency.[2] One standard approach of addressing this problem is by fortifying foods that are commonly consumed with appropriate micronutrients. This approach, however, can introduce new technical challenges as minerals can interact with individual components within a food matrix to change organoleptic properties such as color, texture, and flavor. To this end, iron is known to interact with organic diacids to create colloidal systems.[3,4] Short-chain diacids such as succinic acid and fumaric acid are commonly used to regulate acidity and naturally occur in ingredients, and consequently can promote colloid formation in food products. Despite this, there are few studies that investigate colloid formation in the presence of such food-relevant acids, and studies that use conditions that are appropriate for a food setting, e.g. the use of non-toxic solvents and lower temperatures, are even scarcer. In this work, we investigate the formation of systems such as colloidal gels from iron salts and commonly used diacid acidity regulators. Furthermore, we probe the impact of various synthetic parameters, e.g. pH and formulation ratios, on how they can influence the resulting colloids and their material properties. In doing so, we shed light on an underexplored area of challenges related to mineral fortification in foods.

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Processing Conditions Influencing the Foaming Ability during Vacuum Foam-Drying 163

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ABSTRACT

Vacuum foam-drying is a drying technique which evaporates a solvent at reduced pressure and at ambient temperature. The avoidance of freezing (freeze-drying) and high temperatures (spray drying) offers milder drying conditions for thermal sensitive colloids (such as protein, cells, bacteria, and food stuffs). Vacuum foam-drying can be divided into two sections, a primary drying section, and a secondary drying section. The primary drying is responsible for creating a stable foam, whilst the secondary drying removes trapped residual water by diffusion and desorption.

This project focuses on the primary drying stage and specifically investigates the processing conditions' ability to influence foaming and to stabilize foams. Performed experiments highlighted critical conditions necessary for foam initiation and foam stabilization. Bovine serum albumin (BSA) was used as a model protein and formulated in a sucrose (SUC), with or without dextran (DEX), matrix. The BSA/SUC formulations were dried in a set of different process and formulation conditions, including shelf temperature, chamber pressure, BSA/SUC/DEX ratio, and total solids. The stable foams were assessed in terms of macrostructure, transition time into a stable foam, rate of evaporation, product temperature profile and viscosity.

Conducted trials demonstrated an interesting interplay between the process parameters and the generation of a stable foam. Moreover, the stabilization of a stable foam seems to depend on the protein's surface activity and the properties of the matrix former. This was also investigated by evaluating the surface tension and surface rheology properties and compared during foam formation.

Vacuum foam-drying is a drying technique, which employed correctly introduces new possibilities for drying of proteins (and other biologics).

Impact of acid addition and heterogeneous distribution of sodium chloride on saltiness in bread 177

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ABSTRACT

Excess sodium consumption increases the risk for high blood pressure, which is associated with cardiovascular diseases, leading to premature deaths. The current global sodium consumption exceeds recommended daily intakes and there is a great need to reduce the sodium content in foods for a healthier society. New techniques are needed to reduce the sodium content in foods without hamper the functionality.

Many foods contain sodium as an ingredient and bread is one of the major dietary sources of sodium in large parts of the world. This work investigated the effect of combining sensory interaction principles (acid addition) and heterogeneous distribution of NaCl in bread on sensory properties, structure, and NaCl distribution [1]. Breads were prepared in three different arrangements of NaCl distribution: homogenous, layered, and layered with lactic acid. Within each arrangement, four sodium chloride levels were tested.

Results obtained by sensory panel for perceived saltiness, sourness, and qualitative texture will be presented and discussed. The effect of acid addition and sodium reduction on stiffness obtained by rheology will be demonstrated. Measurements of the NaCl distribution determined by X-ray fluorescence microscopy (XFM) and the bread structure will be presented to discuss the importance of migration on saltiness.

It was found that the perceived saltiness was significantly enhanced in breads beyond heterogeneous NaCl distribution when lactic acid was added, see Figure 1. Stiffness measurements were affected by layering of bread, the layers without NaCl were stiffer with an increase in overall salt concentration. XFM measurements showed that the heterogeneous distribution of NaCl remained after baking and storage. The current study demonstrates the potential of combining principles of pulsation of taste and sensory interactions together to enhance salt perception, and hence suggesting the approach as a possible further strategy for NaCl reduction in bread.

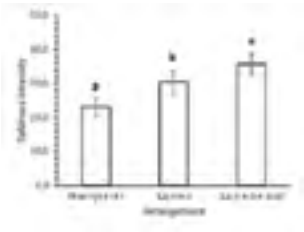

Figure 1. Mean saltiness intensities as a function of dough arrangement.

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Structured lipid systems of fractionated milk fat and olive oil 181

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ABSTRACT

Anhydrous Milk Fat (AMF) is an essential ingredient in the dairy industry, renowned for its distinctive flavor, texture, and nutritional properties. AMF consists of a variety of triacylglycerols (TAGs), primarily composed of saturated fatty acids, each possessing distinct crystallization properties. This characteristic enables AMF to effectively function as a structuring agent across a broad range of applications. Structured lipid systems present an innovative approach for substituting fats in food products. The ability of AMF to structure has gained considerable attention in recent years due to its crucial role in shaping the physical and sensory qualities of different dairy and non-dairy products. Dry fractionation is a fundamental process that further enhances the functionality of AMF. By selectively segregating TAGs based on their respective melting points, fractionation allows for the customization of AMF properties.

In this study, dry fractionation of milk fat was conducted, and the resulting fractions were characterized using various techniques, including gas chromatography (GC), microdifferential scanning calorimetry (μDSC), Fourier-transform infrared (FT-IR) and Raman spectroscopy, rheology, polarized optical microscopy, and confocal laser scanning microscopy (CLSM). Findings from GC, FT-IR, and Raman spectroscopy indicated differences in the unsaturation degree and carbon chain length of the milk fat fractions, leading to variations in the fractions' crystallization temperatures. μDSC, microstructure analysis, and rheological assessments revealed modifications in thermal properties and microstructure among the fractions. Furthermore, the structuring ability of AMF's fractions was evaluated through CLSM, μDSC, and rheology for oleogel formation. The results demonstrated an enhanced gelling capacity when employing AMF fractions, and the thermomechanical properties of AMF were simulated using a low-saturated fat oleogel system.

Fractionation is crucial in enhancing the ability of AMF to structure, making it a promising tool for creating healthier, low-fat options while retaining the desired texture and creaminess.

Acknowledgements: This project was co-founded by Greece and European Union (Project name: Gen-Sheep Milk, Project title: M16SYN2-00069).

Water in Fat Filled Milk Powder – New Insights by Magnetic Resonance Spectroscopy 184

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ABSTRACT

Water is a principal component of all dairy products and significantly affects their properties. Milk powders, although almost devoid of water, may be exposed to high relative humidity if stored at inappropriate conditions. This work examines water in hydrated milk powders – specifically fat-filled milk powder – by employing nuclear magnetic resonance (NMR) spectroscopy. Free Induction Decay (FID), CPMG, and Inversion Recovery (IR) measurement were undertaken at several relative humidity levels at both of resorption and desorption conditions. FID measurements at magic angle spinning conditions made it possible to assign and fit the water peak in the chemical shift dimension and quantitatively measure the relative water contents. Water content measurements were accurate enough to observe minor hysteresis effects. Relaxation ordered spectroscopy by CPMG and inversion recovery methods measured ^{1}H chemical shift and relaxation time distributions at several relative humidity levels. T_1 and T_2 of water increased with higher relative humidity – indicating the occupation of increasing larger spaces by water. Qualitative relaxation dispersion experiments indicated the possibility of exchange at the 100% relative humidity condition.

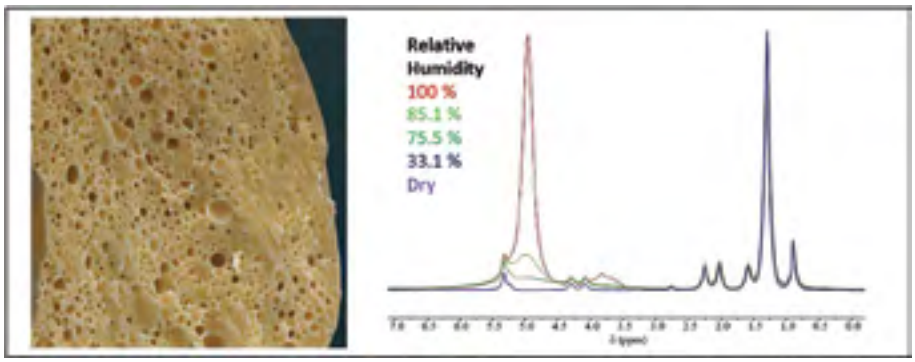

Figure 1. Fat-filled milk powder as measured by scanning electron microscopy (colorized secondary electron image, left) and NMR ^{1}H chemical shift spectra (2.5 kHz MAS, 400 MHz, 15 °C)

Acknowledgements: Authors would like to thank Fábio Mariz Maia Neto, Ramon Liebrechts, and Rebekka Klemmt for assisting in sample preparation/measurement.

Effects of high hydrostatic pressure treatment on structural, techno-functional and rheological properties of sesame protein from sesame cake 207

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ABSTRACT

"Protein modification" refers to the process of changing the molecular structure or several chemical groups of protein with specific methods for improving techno-functionality of proteins. Modification of plant-based proteins offers the opportunity to make them highly functional components for food systems by altering their physicochemical and limited techno-functional properties. In this study, the modification of sesame protein isolate extracted from sesame cake with high hydrostatic pressure (HHP) was carried out. For this purpose protein dispersions (4%) were subjected to HHP treatment (up to 600 MPa) and the structural, techno-functional and rheological properties of the sesame protein were determined. The solubility of sesame proteins increased from 54.28% to 80.12% with HHP treatment up to 400 MPa and obtained a minimum (11.06 µm) and maximum (36.96 mV) values in particle size and absolute zeta potential, respectively. Considering the control sample, it was determined that the HHP caused changes in the SDS-page band intensities. The free-SH group and surface hydrophobicity (H_0) for control were determined as 4.15 µmol/g protein and 25.47, respectively, and HHP treatment at 400 MPa increased free-SH group (8.21 µmol/g) and surface hydrophobicity 41.14 than others. Similarly, the maximum water and oil holding capacities, foam capacity and emulsion stability index of sesame protein were obtained by applying 400 MPa pressure. The FTIR results indicated that HHP treatment increased β-sheets and reduced α-helix, and β-turn structure. The samples treated with 1 MPa and 600 MPa pressure exhibited shear thinning behavior, while the others exhibited Newtonian type behavior. The highest viscosity was determined in the samples subjected to 200 MPa pressure. HHP treated samples were more elastic than control sample and gel formation temperature decreased with increasing pressure. Overall, HHP could constitute an important technological approach for improving the techno-functional properties of sesame protein as a functional ingredient in food system.

Keywords: Sesame protein, protein modification, high hydrostatic pressure treatment, protein structure, techno-functional properties

Acknowledgments: This study was supported by the Scientific and Technological Research Council of Turkey (TOVAG 120O773).

Food-grade bigel systems as carriers for bioactive carotenoids: Potential for extrusion-based 3D printing 242

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ABSTRACT

Bigels are hybrid gel systems, obtained through a combination of hydrogels and oleogels. The manufacture of 3D printed food models, especially with bigel systems, have the potential to encapsulate bioactive components, to protect and release labile molecules in a complex matrix. The main objective was to evaluate the capacity of bigels as carriers of natural carotenoids. Likewise, we seek to understand the effect of different proportions of bigels constituents on their structural and printability properties. For this, edible ingredients were used and different formulations of bigels were tested, both containing oleogel composed of beeswax and sunflower oil and two different types of hydrogels, agar and gelatin both added with xanthan gum, the bigels formulated in three HG/OG proportion (80:20; 70:30; 60:40). Pitanga (*Eugenia uniflora*) extracts were considered for the incorporation of carotenoids, and concentrations of 800-1600 µg/100g were applied in the oleogel fraction. The bigel apparent viscosity tended to decrease with the decrease of HG in proportion HG:OG (from 80:20 to 60:40). The pitanga carotenoids, diluted in the oleogel fraction, had a discrete distribution throughout the hydrogel structural network, and were not dominant in this dispersing phase. The printability of these bigel inks is strongly related to the rheological characteristics of these matrices, as they presented pseudoplastic behavior with evidenced shear-thinning properties. In agar bigels (Figure 1G-L), all extruded formulations allowed for a good dimensional resolution in an appropriate end-product shape, with all layers of the designed drawing adequately built up, on the other hand, objects printed with gelatin bigels (Figure 1A-F) showed greater differences in their dimensions. These findings suggest that the use of carotenoids from pitanga may represent a promising strategy for the development of bigels with improved functional and coloring properties.

Figure 1. Printability of gelatin-based bigel (A-F) and agar-based bigel (G-F) formulations, at different HG:OG proportion: A-B and G-H (80:20), C-D and I-J (70:30), and E-F and K-L (60:40), and at different pitanga carotenoid concentration: 800 µg/100g (A, C, E, G, I, K) and 1600 µg/100g (B, D, F, H, J, L).

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Exploring the Semi-automated Table-top Transmission Electron Microscopy Technique MiniTEM™ for Characterization of Protein Aggregates 244

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ABSTRACT

Protein aggregates are common in several areas, such as food processing and biological pharmaceuticals. Characterization is essential when assessing the quality and stability of different systems since it can decrease the quality or cause issues in the production line. However, aggregates can be difficult to characterize as they have a broad size range from nanometer to micrometer and different shapes. Today, it is not possible to obtain information of the whole size range of aggregates with only one technique, and it is highly recommended to use orthogonal techniques to characterize systems better. The information provided from different techniques can for example be size, qualitative, quantitative, shape, or structural information, and which technique to use should, therefore, be chosen carefully depending on the required information. We address the characterization of protein aggregates and demonstrate what type of information the novel Transmission Electron Microscope (TEM) based technique miniTEM (Vironova AB) for studying protein aggregates can provide compared to dynamic light scattering (DLS). We do this using a practical example of heat-induced aggregation of beta-lactoglobulin as a model protein. Results indicate that the technique effectively shows the shape of the aggregates, which can be further assessed by image analysis of shape parameters like ferret diameter and skeleton based shape factors.

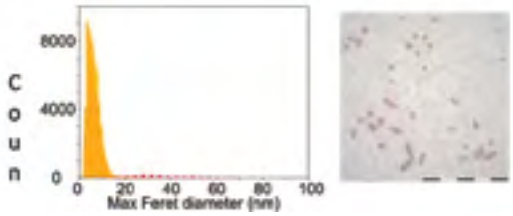

Figure 1. Size distribution from image analysis of MiniTEM™ and image with marked native protein and aggregates in yellow and red, respectively.

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Impact of high intensity ultrasound on the colloidal and functional properties of Vicia villosa protein isolate 247

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ABSTRACT

The global population growth, increasing protein consumption, and some concerns around animal protein production, have prompted the need for alternate protein sources. Plant proteins play a signifcant role in human nutrition. However, due to the compact structure of globular proteins, they have poor functional properties compared to animal proteins.

Vicia villosa belongs to the *Fabaceae* family and is mostly cultivated for stock-feed and human consumption. *Vicia* proteins have the potential to be a new and unique source of proteins. Sonication, as a non-thermal processing leads to covalent modification of structure and functional properties of protein. It is of great interest to know how high-intensity ultrasound (HIUS) treatment affects the properties of *vicia villosa* protein isolate (VVPI). This research aimed to study the impact of HIUS treatments on physicochemical and techno-functional properties of VVPI; 8% (w/w) protein suspensions were prepared and treated at different exposure time (5, 10, 20, and 30 min in 20-kHz fixed frequency, 500 W and pulse treatment 5 s On and OFF). High-intensity ultrasonic treatment, because of cavitational forces, reduced the particle size, turbidity, and viscosity of VVPI dispersions with a significant increase in solubility, free sulfhydryl, and surface hydrophobicity. The highest reduction in particle size from 387.43 µm to 175.14 µm was observed in VVPI treated for 30 min. Hence, the partial unfolding, structural changes and re-formation of inter-molecular bonds resulted in significant improvement in WHC and gelation properties. The best improvement of functional properties was obtained after 20 min treatment.

Development of edible coating with *Chlorella vulgaris* enriched with encapsulated bioactive compounds: Application in fresh raspberries 262

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ABSTRACT

Berries are becoming more and more popular due to their high nutritional content. Typically, oxidative reactions, respiration processes, spoilage bacteria, and storage in abusive temperatures that may occur in the supply chain can lead to quality degradation and short shelf-life of berries. Extending the shelf-life of berries with minimal processing so as not to affect the nutritional content, physical characteristics, or sensory attributes is still a difficult task for the food business. The application of edible coatings in berries can be used to extend the commercial shelf life while the enrichment of edible coatings with encapsulated bioactive compounds can enhance the nutritional value.

The objective of this study was to investigate the development of *Chlorella vulgaris* based edible coatings and their enrichment with encapsulated bioactive compounds to extend the shelf life of fresh raspberries.

Protein and starch were extracted from *Chlorella vulgaris* with appropriate protocols and were combined with plasticizers and other ingredients, in order to develop the final coatings. Electrospinning was used to complete the encapsulating process, of phenolic compounds from plant sources.

Berries were immersed in the edible coating solutions and were dried in air, until the coatings were dried on the berries. Afterwards, the shelf-life of the product was determined. Samples were stored at 4° C and selected quality attributes i.e., color, weight loss, antioxidant activity, and spoilage microorganisms were monitored at predetermined time intervals. According to the results the application of bioactives enriched *Chlorella vulgaris* edible coating in raspberries led to shelf-life extension and enhanced quality.

Acknowledgements: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007783

Recovery of polyphenolic bioactive compounds from *Rosmarinus officinalis* L. and their encapsulation using electrospraying process 263

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ABSTRACT

In recent years, the integration of plant extracts into food products has been undertaken to enhance their functional properties. Rosemary (*Rosmarinus officinalis* L.) is a rich source of polyphenolic bioactive compounds, including phenolic acids and flavonoids, offering beneficial properties for human health. However, these components are susceptible to degradation during processing and storage, prompting the use of encapsulation into suitable matrices as a promising technique to enhance their stability [1].

The primary aim of this study was: a) the recovery of antioxidant ingredients from rosemary plant and their encapsulation into nano/micro structures, b) the characterization of the developed structures, and c) the evaluation of their release rate and stability during storage conditions. Notably, the recovery of these bioactive ingredients was optimized using microwave/ultrasound-assisted extraction (MAE/UAE) and a combination of them. The extraction parameters including MAE and UAE power, the solid: liquid ratio, and the extraction time, were optimized in terms of total phenolic content using the response surface methodology (RSM) and central composite design (CCD). The recovered extracts were evaluated regarding extraction yield, antioxidant activity and total phenolic content (TPC). The extract, obtained under optimized conditions, was encapsulated within zein nano/micro structures through the electrospraying process. The encapsulation efficiency (%EE) was assessed through High-Pressure Liquid Chromatography (HPLC), morphology was characterized by Scanning Electron Microscope (SEM) and antioxidant activity was determined via DPPH scavenging activity. Additionally, the confirmation of the presence of antioxidant components in the examined structures was conducted using the ATR-FTIR technique. Finally, the release kinetics of the encapsulated active ingredients were studied over time under different storage conditions. According to the results, phenolic extracts can be efficiently recovered from rosemary and encapsulated via the studied method. Furthermore, the encapsulated structures could be applied as food additive, providing antioxidant activity.

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Mapping Phase Distributions of Vacuum Foam-Dried Biologic in a Matrix System 264

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ABSTRACT

Proteins are large molecules with multiple domains that typically demonstrate amphiphilic attributes and adsorbs to surfaces. However, surface interactions can affect the protein structure and result in decreased biological activity, aggregation, and/or degradation. Previous studies have shown that the inclusion of small-molecule surfactants can compete with proteins for surface adsorption in spray-drying (1). This also occurs to a lesser extent in freeze-drying (2).

This study focuses on mapping the distribution of proteins in a matrix system with and without the presence of surfactants, manufactured by vacuum foam drying. A recombinant bile salt stimulating lipase (lipase) was used as a model protein, in a sucrose/dextran (SUC/DEX) matrix with and without the surfactant α-dodecyl glycoside. The distribution of components was analyzed by Scanning Electron Microscopy (SEM), X-ray Photoelectron Spectroscopy (XPS), Confocal-Raman, and Time of Flight Single Ion Mass Spectrometry (ToF-SIMS).

The experiments showed the possibility of constructing a schematic overview that distinguished the phase distributions of the lipase in a matrix system, dried by vacuum foam-drying. Photographs will demonstrate the overall structure of the dry solid foam, while SEM will show the morphological characteristics of the vacuum foam dried lamellae. The surface composition of foam lamellae in a very thin surface layer (few nm) will be quantified by XPS and ToF-SIMS will highlight the lateral distribution of components at the surface. Confocal-RAMAN will provide knowledge on the internal distribution of components at a larger length scale (approx. 300 nm). These technologies will together provide a map highlighting the distribution of components in the dry solid foam, produced by vacuum foam-drying.

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Silk's Insights for Food Colloids: Investigating Stability of Cylindriform Silk Using A Multimodal Analysis Tool 273

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ABSTRACT

Our research delves into the colloidal stability encountered during the sol (liquid)-gel transition of cylindriform silk, recognizing that our current understanding of controlling stability and the transition of spider silk is limited. The primary objective is to comprehend the intricate balance required to regulate silk protein stability and assembly across multiple time and length scales. This investigation draws parallels with analogous challenges faced by food colloidal systems, particularly systems that undergo a transition from liquid to gel-like states, where controlling particle aggregation and achieving stable structures pose hurdles. Exploring how spider silk achieves colloidal stability will provide a foundation for the potential technological transfer to design and engineer stable food colloid systems.

Our study focuses on the cylindriform silk system responsible for forming spider egg casings. The cylindriform silk protein undergoes a rapid self-assembly transition from predominantly stable alpha structures (unique to this silk type) to ordered beta structures. Remarkably, spiders exhibit stringent control over premature aggregation, imperative in the biology of silk spinning. However, the persistent challenge of uncontrolled silk protein aggregation during *ex vivo* studies inhibits a comprehensive understanding of their stability dynamics. This is, in part, due to the fact that most silk studies explore dragline silk proteins, which lack a defined structure and are prone to insolubility in solution. Therefore, our recombinant cylindriform silk protein, designed and produced with the goal of being stable and containing fully folded α-helical structures, will be used to explore the fibrillation process. This recombinant system allows for more control over the silk protein production and fibrillation process compared to the use of native silk.

Integral to our study is the application of the innovative analytical tool, NUrF [1] (Neutron small-angle scattering, UV-vis, Raman, and Fluorescence). NUrF, a versatile and non-destructive method, provides mesoscale insights into the size, shape, internal organization, complex formation, and structural alignment of silk proteins during fibrillogenesis. This capability allows us to extract rate laws throughout silk fibrillation, offering a comprehensive understanding of the structural transitions from stable alpha structures into ordered beta sheet protein superstructures. This study lays the groundwork to investigate other colloidal systems across a diverse range of applications, including the field of food colloids.

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Chickpea proteins and cellulose nanocrystal interactions: Effect of nanocrystal concentration on protein aggregation 284

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ABSTRACT

Chickpea protein isolate (CPI) has good functional properties such as high solubility and foaming properties, which permit wide applications in the food industry. Cellulose nanocrystals (CNC) have excellent physical and chemical properties and are considered novel food ingredients. CNC have excellent properties as stabilizers and thicknesses in aqueous systems. This study aimed to characterize the interactions of chickpea proteins with CNC in a model of milk analogs, and to understand the impact of CNC concentration on these interactions. CPI dispersions (3%) with and without CNC (0%, 0.5%, 1%, and 3%, weight/volume) were characterized in terms of charge, size, aggregation index, protein solubility and hydrophobicity, hydrogen bond interactions, and secondary structure of proteins analyzed by FT-IR and Raman spectroscopy. The results suggest that the surface properties and molecular ordered structure of chickpea proteins were significantly ($p<0.05$) affected by the presence of CNC, and this behavior was also observed with increasing CNC concentration. The negative charge of native CPI (*-29 mV*) was significantly ($p<0.05$) decreased at 1% (*-16 mV*) and increased at 3% (*-34 mM*) CNC. The z-average of CPI and the aggregation index increased with the incorporation of CNC (*CPI < CPI-CNC-0.5% < CPI-CNC-1% < CPI-CNC-3%*). Protein solubility increased with increasing CNC concentration (*26% to 51%*). The tryptophan fluorescence of CPI was reduced by the incorporation of CNC. Interactions through hydrogen bonds between CPI and CNC were observed through FT-IR and Raman results. The incorporation of CNC into the milk analog system as a stabilizer ingredient could improve the digestibility of chickpea proteins because they increase the α-helix structures and the disordered state. Although confirmatory digestibility studies are necessary to validate this statement. This research enriches CPI and CNC applications in plant-based texture-modified beverages. Understanding conformational and structural behaviors is important during food formulation to control the digestibility of beverage products.

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Anthocyanins extracted with NADES applied in potato starch inks for 3D food printing: evaluating starch retrogradation and color stability 285

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ABSTRACT

Application of the natural deep eutectic solvents (NADES) is a promising green method to obtain bioactive compounds from natural sources. In prior research, we produced an anthocyanin rich extract from *Euterpe edulis*, one Brazilian native fruit that displayed high antioxidant activity. The extract obtained shown high thermal stability and are ready to be applied as natural colorant in a variety of food products. In this study, we explored the incorporation of the anthocyanic extract to 3D printed food, using potato starch as hydrocolloid for ink development. Starches are commonly used to create printable food inks, but retrogradation (water release) of starches makes this process challenging. We evaluated through experimental design how the incorporation of this extract modifies the retrogradation of starch during storage (up to 8 days) and if the temperature that the extract is incorporated affects the color of the model printed (30ºC to up 80 ºC) in different concentrations, since anthocyanins can be susceptible to thermal degradation. The results were able to build surface models (Rsqr0.89), showing an increased response with concentration, reducing the starch recrystallization and therefore water exudation of the samples likely due to the abundance of cations and OH groups from anthocyanin chemical structure. Temperature and time of storage did not influence intensity of color of the printed models, and therefore the process can be performed at 80 ºC without significant damage to the food color. The morphology of the printed structures displayed a variety of aspects with no clear correlation with the evaluated parameters.

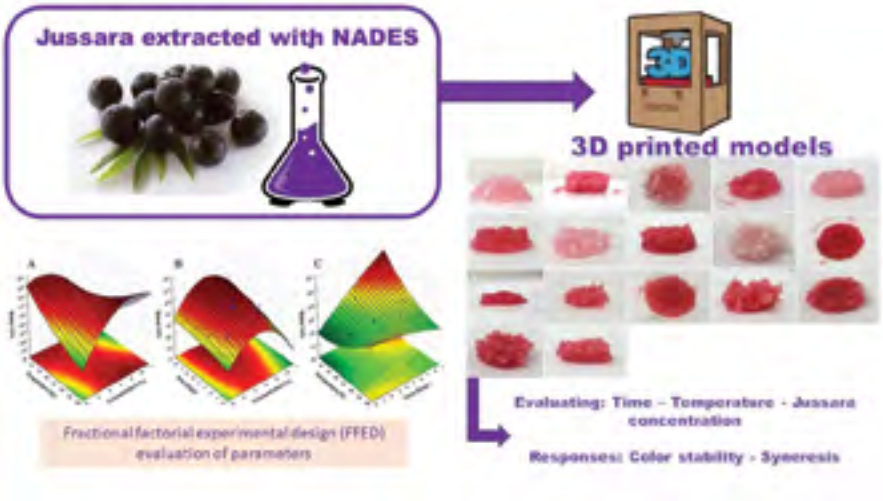

Figure 1. Graphical abstract of the study. The jussara extracted with NADES was used to create 3D models with potato starch inks. Parameters of time, temperature and extract concentration were evaluated and resulted color and exudation of water were calculated via fractional factorial experimental design (FFED).

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Dynamics of Water in Pickering Particles: Insights from Quasi Elastic Neutron Scattering and Thermal Analysis 292

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ABSTRACT

Ensuring the production of safe and nutritious food while embracing sustainability is a pressing challenge in Europe's research and innovation agenda. The PICKFOOD project, supported by the EU, addresses this challenge by focusing on Pickering emulsions. Dual-wettable particles, exhibiting affinity for both oil and water phases, play a crucial role in imparting stability to these emulsions. This research aims to develop surface-functionalized fumed silica as food-grade particles via freeze-drying process. To achieve this, we synthesized bubbles and antibubbles with prolonged durability using hydrophilic and hydrophobic functionalized silica nanoparticles. Stable bubbles and antibubbles were achieved by employing a combination of adsorbed particles to stabilize air-water interfaces [1]. The next step involved the characterization of these particles using advanced neutron scattering techniques, particularly Quasi-Elastic Neutron Scattering (QENS) and thermal techniques like Thermogravimetry analysis coupled with Infrared and Mass Spectroscopy. Our goal was to explore the dynamics of water populations within these particles, as hydration levels play a pivotal role in emulsion macro-stability. The neutron scattering results on five samples unveiled the role of rigidity in determining the time- and length-scales of low-frequency collective vibrational dynamics in silicas. These dynamics manifest as a spectral feature known as the Boson Peak (BP), common to disordered materials [2]. The emergence of the BP provides insights into the level of disorder and hardness of the samples. This consistency in physical mechanisms establishes a connection between silica macromolecule vibrational behavior and nanoscale structural irregularities. Our findings not only contribute to the broader understanding of food colloids but also offer empirical benchmarks for elucidating relationships between molecular structure and rigidity. This connection paves the way for engineering samples for novel applications, such as emulsions. The poster presentation invites engagement and discussions on the intricate interplay between water dynamics, Pickering particles, and the implications for emulsion stability.

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Rheological and tribo-rheometrical properties of milk and plant-based milk alternatives 297

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ABSTRACT

Both, texture, and mouthfeel, are highly related to the microstructure of foods and are therefore crucial terms for consumer choice and acceptability. Consequently, to enhance customer acceptance, both formulation and production processes must be tailored to achieve certain flow properties, texture and mouthfeel accordingly.

Eating and swallowing are a highly dynamic process, and the oral processing undergoes various stages. At first, a bulk dominant stage takes place involving flow and deformation under shear, compression, and elongation. After that, the oral processing transitions to surface property dominant characterized by closed contact interaction and lubrication of oral surfaces. [1,2]

Rheology is already a widely used technique in the chocolate or dairy industry, among others, which serves the characterization of the bulk property dominated regime. However, given that the oral cavity comprises of the tongue touching and sliding on the palate in the presence of a lubricating food product, tribological measurement techniques are required to quantify the frictional properties of foods. For this reason, this technique is gaining more popularity as a research tool. However, the evaluation of the obtained data is still a topic for discussion.

In order to showcase the use of tribology as industrial relevant tool to quantify and compare mouthfeel, this contribution focuses on the impact of different types of commercially available plant-based milk alternatives on the rheological as well as tribo-rheometrical properties compared to different cow milk references. For this, a rheometer equipped with a tribo-rheometrical measuring geometry is used and Stribeck curves together with the respective rheological flow properties of each food product will be compared. This research contributes to understanding the differences between plant-based milk alternatives and their animal-based references regarding their flow and lubricating properties. This has the potential to leverage the variety of options available to meet the consumer's expectations.

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Techno-functional properties of starch of different botanical sources as affected by ball milling 301

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ABSTRACT

Starch, a renewable biopolymer derived from various plant sources, serves as a major ingredient for food formulations despite in its native state, the technological functionality is rather reduced and its applications are constrained. Physical techniques are increasingly used to induce structural modifications that enhance starch performances and, among others, ball milling (BM) is one of the most promising and innovative ones.

Aim of this study was to investigate the changes in properties and functionalities (i.e. Swelling power-SP, Cold water solubility-CWS, water-WHC and oil holding capacity-OHC, rheological and thermal) of starch of different botanical sources (potato, tapioca and wheat) induced by BM applied for different time (5, 15, and 30 min) at a constant speed (350 rpm).

Overall significant modifications ($p < 0.05$) of the technological functionalities as a function of BM time were observed. In particular, CWS and SP increased ($p < 0.05$) in all BM starches compared to the corresponding native one. Among BM samples for 30 min, the tapioca starch showed a three-fold higher SP than the other botanical origins and all BM-starches ($P< 0.05$) showed higher OHC compared to native counterparts. Generally, the WHC was positively correlated with BM milling time to a different extent depending on the botanical origin.

By thermal analysis, a progressively lower gelatinization enthalpy and onset temperature of the BM-starches compared to those of the native ones at increasing BM-time, was observed, suggesting a corresponding decrease of the granule crystallinity. Pasting tests of the aqueous starch dispersions and rheological measurements of the corresponding set gels highlighted lower elastic modulus of the BM-samples and a weaker gel formation in all the BM-starches of different origin.

The results highlight the effects of ball milling on starches from different botanical sources providing scientific support for its potential use for starch modification.

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Effect of ultrasonication on the mechanical properties and microstructure of yoghurt products 310

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ABSTRACT

The aim of this project was to investigate the modification of the mechanical properties and microstructure of yogurt using ultrasound, for milk homogenization. This method has shown excellent results in reducing the size of milk fat globules, thereby influencing the mechanical properties and microstructure of the yoghurt produced.

The effect of ultrasonication on both whole and skimmed milk was investigated by varying the amplitude and time interval. Acidification of the yoghurt was achieved by using a starter culture of lactic acid bacteria. The droplet size (analysed by light scattering) and microstructure (examined by confocal microscopy) of the sonicated emulsions were studied. At the same time, yoghurts were evaluated for their microstructure, rheological properties, water retention capacity, acidification kinetics and SDS page electrophoresis.

The results showed that ultrasonication effectively reduced the droplet size of milk fat globules, resulting in a change in the microstructure of the yoghurts and a reduction in syneresis. This phenomenon has a significant effect on the rheological properties, resulting in the formation of stronger gels. It also affected the water retention capacity and accelerated the rate of acidification.

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Oil-in-Water Emulsions Stabilised with Native Corn Starch and Olive Leaves Phenolic Extract: a tribological study 311

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ABSTRACT

In this study, the tribological behavior of oil-in-water model emulsions stabilized by native corn starch particles in association with a surface-active olive leaves phenolic extract (OLE) was studied. Preliminarily, starch particles were submitted to a high-pressure homogenization pre-treatment and were then separated, by sedimentation, into small (median value ≈2.5 μm) and large (median value ≈ 17 μm) particles. Ten % (w/v) o/w emulsions using native corn starch particles were prepared with OLE as an emulsifier and characterized for particle size, microstructure and tribological behavior; different starch and OLE combinations were tested in the emulsion formulations. OLE and starch particles were both needed for systems structuration, providing stability with different mechanisms. OLE triggered oil droplet formation acting as a low molecular weight emulsifier, while starch particles played a different role in the stabilization of the emulsions based on their size: the small starch particles provide stability by adsorbing onto the o/w interface, while the large particles provide stability by forming an interconnected network in the continuous phase, which embedded the oil droplets. The tribological study showed that emulsions stabilized by small particles showed higher friction coefficients. In these emulsions, the stable emulsion droplets provided particle lubrication. In emulsions stabilized by large particles, lower friction coefficients were observed due to the low stability of the oil droplets that underwent coalescence phenomena providing oil film lubrification. Such findings demonstrated that the size of starch particles played an important role in the stabilization mechanism of the emulsions as well as of their lubrication properties.

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Synchrotron X-ray microtomography of the freeze-drying process in-situ 312

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ABSTRACT

Freeze-drying is one of the most common ways to enhance the shelf-life of probiotics and pharmaceutics. The impact of freeze-drying process on the structure poses a significant challenge for probiotics, as inadequate cell encapsulation due to too thin dried material can harm the stability of probiotics. The main purpose of this study is to follow the freeze-drying process in-situ to understand how the freezing, annealing and drying steps affect the final material structure.

Tomographic imaging techniques, in this case Synchrotron X-ray microtomography (SRμCT) offers the potential to evaluate the 3D-structure of a freeze-dried probiotic product and to follow the evolution of the matrix during freeze-drying. To capture the dynamic events of freeze-drying in 4D at high spatial resolution, it is necessary to use synchrotron radiation which offers a higher photon flux, thus lowering the acquisition time.

A miniaturised freeze-dryer (an in-situ sample environment) was constructed for usage at the ForMAX beamline at the MAX IV Synchrotron (Lund, Sweden), in which relevant temperatures and pressures could be obtained. Lab-based microtomography (μCT) and SRμCT were carried out on static freeze-dried samples and during in-situ freeze drying, respectively, and the results were compared for dried materials, as well as frozen samples.

Using SRμCT the process from freezing, annealing and primary drying could be followed in real time. The results provided novel insight into the annealing process, revealing the transformation from a very fine frozen structure to a structure with larger ice crystals. The formation of cracks in the ice was also observed as a consequence of the annealing process. It is evident that the material only changes to a minor degree during the actual freeze-drying and that freeze-drying occurs faster in some parts of the samples. It was confirmed that the final ice crystal structure is the main contributing factor to the final structure of the dried product.

Acknowledgements: This research was funded by the Swedish Governmental Agency for Innovation Systems (VINNOVA) under grant agreements 2020-00824 (SBP, EL, JE, SHa) and 2018-04730 (MW, BB, AMF), and by BioGaia AB (SBP, SHå).

Understanding microstructure and physicochemical properties of yeast biomass-stabilized Pickering emulsions 321

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ABSTRACT

Among single-cell proteins (SCPs), yeast shows an untapped potential for use in food formulations. It offers the possibility to address the food security challenge and serve as a sustainable protein source. Nevertheless, there is a limited understanding of how yeast cells may contribute to Pickering emulsification.

This study aims to compare yeast biomass from three different types of yeast for their ability to stabilise Pickering cell-stabilized oil-in-water (O/W) emulsions. Three strains - *S. cerevisiae*, *C. utilis* and *Y. lipolytica* - with 40 to 60% intrinsic protein content and approved for food use were cultured through batch fermentation in glucose-rich media. The biomass was characterised for its size, shape and capacity to stabilise the oil-water interface. Microstructure was examined at multiple length scales using a scanning electron microscope (SEM) and a confocal laser scanning microscope (CLSM) to determine their shape and size. Emulsion stability was monitored for a month using static light scattering and CLSM.

Findings reveal marked differences in shape and size among the three strains whilst demonstrating different capabilities in stabilising oil-in-water emulsions. Both *S. cerevisiae* and *Y. lipolytica* cells were spherical, ranging in diameter from 2 to 7 µm, whilst *C. utilis* cells had an elliptical shape with a 3:2 aspect ratio ranging in length from 6 to 8 µm. *S. cerevisiae* and *Y. lipolytica* showed aggregation of cells in the bulk phase. *S. cerevisiae*-stabilised emulsions effectively prevented droplet coalescence with mean droplet size (D[4, 3]) ranging between 15 to 30 µm, whilst emulsions made using *C. utilis* and *Y. lipolytica* showed rapid coalescence. Ongoing studies are characterising cells' interfacial properties to elucidate whether the mannoprotein at the cell surface provides interfacial benefits in stabilising droplets against coarsening in case of emulsions stabilised by *S. cerevisiae* cells.

Figure 1. Illustration of methodology. a) Protocol for the production of biomass and b) different techniques for microstructural analysis and characterisation of biomass (created using BioRender.com)

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P3. SUSTAINABLE FOOD COLLOIDS CLEAN, ENVIRONMENTALLY FRIENDLY, PLANT-BASED

Enhancing the Quality of Plant-Based Meat Analogues: Effects of Methylcellulose on Mechanical Properties and Texture 18

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ABSTRACT

The production of meat is environmentally inefficient, impacting land and freshwater resources and contributing to deforestation and biodiversity loss. To address the challenge of providing enough protein for a growing population while reducing the environmental footprint of the food industry, there is a promising solution: replacing animal proteins with plant-based alternatives [1].

One such alternative is plant-based meat analogs, created through high-moisture-extrusion cooking. This process utilizes thermos-mechanical energy to transform raw plant proteins into a fibrous structure that closely mimics traditional meat's muscle composition. While the demand for plant-based meat alternatives is rapidly increasing worldwide, consumers still face limited diversity in available products, especially in terms of meat types and protein sources.

To meet consumer expectations, new products must closely replicate the taste, aroma, and texture of meat. However, consumer surveys reveal that existing products often fall short in areas such as texture, juiciness, and mouthfeel. One way to enhance the textural properties of meat analogs is by incorporating hydrocolloids. Hydrocolloids improve water binding in extrudates and may enhance fiber formation. Their effects, however, depend on factors like concentration, interactions with the protein matrix, and molecular features [2].

This study focuses on the impact of methylcellulose on the mechanical properties of pea protein extrudates produced through high-moisture extrusion cooking. Methylcellulose solutions of varying molecular weights were introduced at 0.5 and 1wt% during the extrusion process. The results demonstrate that the Young's Modulus of the extrudates decreases with the addition of methylcellulose, with this reduction correlating with the type and concentration of methylcellulose used. Furthermore, rheological test using a close cavity rheometer were conducted to assess methylcellulose's influence on melt viscosity and uncover potential interactions between the protein and hydrocolloids. This research contributes to improving the quality of plant-based meat analogs and expanding the variety of options available to consumers.

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Food Hydrocolloids, Volume 135, 2023,108199

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Ethanol-treated rapeseed meal protein isolate mediated the stability of corn and olive oil-in-water emulsions 19

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ABSTRACT

Rapeseed meal is a by-product of the oil-producing industry with currently underestimated application. Being rich in protein (38%), it is used as a feed ingredient but in a limited amount due to the presence of some antinutrients. Alternatively, this plant material could be used for the preparation of protein isolates for human nutrition. In the current study, a protein isolate was prepared by isoelectric precipitation (pH 4.5) of alkali-extracted proteins (pH 12) from the rapeseed meal pre-treated with 70% ethanol to reduce phenol and glucosinolate contents. The ethanol-treated rapeseed meal protein isolate (ERPI) was further evaluated for its ability to mediate the stability of corn and olive oil-in-water emulsions under slightly acidic conditions (pH 6). A total of nine model food emulsions for each type of oil were prepared to assess the significant effect of two variables, oil (5, 10, and 15% w/w) and ERPI concentrations (0.25, 0.5, and 1.0% w/w), on emulsion stability [1]. The initial stability was evaluated by Gibbs free energy (ΔG), while the dynamic of emulsion stability was investigated along 7 d by turbidity measurement. The increase in concentration of both types of oil positively influenced the initial stability of the emulsions as indicated by ΔG. At each oil concentration, the three ERPI supplementation levels significantly altered ΔG. While in all olive oil-in-water emulsions, the highest initial stability was achieved by the addition of 0.25% ERPI, in the corn oil-in-water emulsions, lower ΔG values were achieved by supplementing either with 0.5 or 1.0% ERPI. With a reduction in turbidity not higher than 30% at day 7, all corn oil-in-water emulsions supplemented with 0.5% ERPI demonstrated better stability than the emulsions prepared with olive oil. Diversified application of the rapeseed meal as a by-product would contribute to better and more efficient use of natural resources.

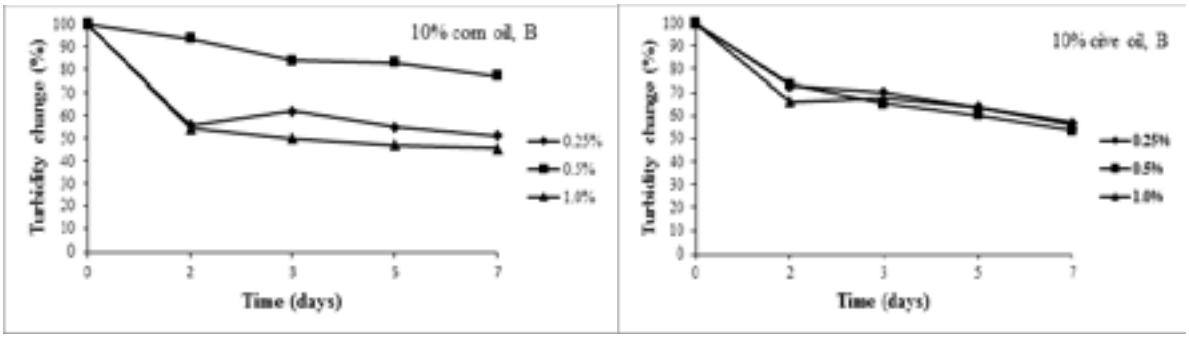

Figure 1. Stability dynamics of emulsions prepared with 10% corn and olive oil and different ERPI protein concentrations (0.25, 0.5, and 1.0%). The means are from three independent measurements. Standard deviations were in the range of 0.48% to 0.51%.

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Dynamic High-Pressure processing and pH-shifting in the solubilization of Sesame isolate protein (Sesamum indicum L.) 20

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ABSTRACT

Most plant-derived proteins suffer from low solubility, which restricts their application in the food industry. This functional property can be improved using physical treatments. The Sesame (Sesamum indicum L.) isolate protein (SPI) was processed using Dynamic High-Pressure technology (DHP) (50, 100 and 150 MPa; 1 cycle; 25°C) at two pHs: neutral (pH 7.0) and alkaline (pH 11.0). Its solubility was evaluated in a pH ranging from 2 to 8. When compared to the unprocessed sample at neutral pH (control – pH 7.0), the SPI processed at 150 MPa and pH 7.0 showed a significant ($p \leq 0.05$) increase across all pH ranges (2-8). Similar improvements ($p \leq 0.05$) were observed at 50 MPa and 100 MPa in the pH ranging from 2 to 5. However, when solubility was evaluated in the range of 6-8, a decrease was observed ($p \leq 0.05$). Regarding the samples processed at alkaline pH, it was observed that solubility in the pH range of 2-5 was higher in the samples processed under all conditions (50, 100, and 150 MPa) compared to the control ($p \leq 0.05$). However, when analyzed in the range of 6-8, the unprocessed control sample was more soluble than the processed sample ($p \leq 0.05$). The Dynamic High-Pressure technique with pH shifting can become an important tool for modifying plant proteins, which is of great interest of the industry, as it increases the use of new protein sources as ingredients in food formulations.

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High Pressure Processing coupled with pH- shifting to modulate the emulsifying behavior of Sesame (Sesamum indicum L.) isolate protein 21

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ABSTRACT

Proteins extracted from industrial by-products (oil extraction) have become very important as improve sustainable aspects the processing chain. These proteins, being of plant origin, have some functional drawback (such as low solubility), making their industrial application difficult. The Sesame (Sesamum indicum L.) protein isolate (SPI) was obtained from Sesame meal. The SPI was processed at High Hydrostatic Pressure – HHP (200, 400 and 600 MPa; 10 minutes; 25°C), at acidic (4.5), neutral (7.0) and alkaline (11.0) pH. The emulsion activity index (EAI) and emulsion stability index (ESI) were evaluated at pH 7 for all treated materials. Processing at pH 4.5 improved ($p<0.05$) EAI for all pressure levels being the highest value at 200 MPa (11.70 m^2/g). Regarding stability (ESI), the treatment of 600 MPa (94.81 min) and 400 MPa (49.20 min) displayed a better stability when compared to the control (34.99 min) ($p<0.05$). The SPI under neutral conditions (pH 7.0) had an increase in EAI only at 200 MPa (24.95 m^2/g), at 600MPa (7.41 m^2/g) and 400 MPa (6.93 m^2/g) there was a reduction when compared to the control (11.57 m^2/g). On the other hand, the opposite occurred in the ESI, the samples processed at 600 MPa and 400 MPa (57.37 and 40.03 min respectively) showed better stability compared with the unprocessed (23.13 min) samples. In alkaline medium (pH11.0) the EAI was higher at 200 MPa (25.01 m^2/g), followed by control (21.33 m^2/g), 600 MPa (15.38 m^2/g) and 400 MPa (10.45 m^2/g); as for the ESI, again the sample processed in 200 MPa (26.41 min) had a higher stability than the others, however, the samples treated at 600 MPa (20.17 min) and 400MPa (19.64 min) did not have a significant difference compared with the unprocessed sample (17.06 min). Thus, HHP processing may be a strong ally for the development of new plant -based ingredients.

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New Food-Grade Wall Material: Complex Coacervation Encapsulation Using Ora-pro-Nobis Mucilage 27

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ABSTRACT

Complex coacervation, widely employed in encapsulation, relies on polymer interactions with opposing charges at specific pH levels, forming a protective barrier for core materials. Common biopolymers adopted include gums, pectins, and proteins. Current global trends promote research into new polymers from plant sources. Ora-pro-Nobis (OPN), native to South America, is an unconventional plant with unexplored potential. Its leaves contain a significant amount of arabinogalactan-rich mucilage with health benefits, including tissue healing, inflammation relief, and anemia treatment. This mucilage has excellent water-absorption properties which are paramount for thickening, gelling, emulsifying, and stabilizing food products. By leveraging advancements in food processing and microencapsulation, it might be a promising wall material for complex coacervation. This work aimed to analyze microparticle formation by altering the combination of wall materials, using OPN mucilage (MU) in combination with type "B" gelatin (GE). By employing a ratio of 2:1 GE-MU and varying paprika resin oil fraction (Φ) in 40%, 33%, and 20% of total solids, we produced particles and observed strong complexation in all samples. The precipitation pH was set at 4.0 (based on Zeta Potential curve). Encapsulation efficiency (EE) and complexation yield (CY) were determined by a spectrophotometer (460 nm) after extracting paprika oil using ethanol. The morphology was analyzed using an optical microscope (Axioscope 5, Carl Zeiss, China). All particles had high EE, from 77 to 92% and high CY, from 93 to 70%, respectively for Φ 40 to 20%. The highest encapsulation efficiency was reached for the lowest Φ , but at this condition the polymer complexation was the lowest. These findings support the effective utilization of OPN mucilage as a new food-grade wall material in encapsulation processes.

Acknowledgements: We acknowledge Research Support Foundation of the State of São Paulo (FAPESP, Brazil) project nº 2022/01606-9; Coordination for the Improvement of Higher Education Personnel (CAPES, Brazil) and National Council for Scientific and Technological Development (CNPq).

Understanding the structure formation of plant-based alginate bioinks in 3D-bioprinting 29

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ABSTRACT

Alginate-protein composite gels are used in various applications in foods or biomedicine. For instance, in 3D-bioprinting, the combinations of alginate and gelatin can be used to produce scaffolds for cultured meat or organ models. Due to the specific techno-functional properties of gelatin, it remains a challenge to replace it with a plant-based protein. Therefore, the aim of this study was to characterize the effect of plant-based proteins such as pea protein on the gelation behavior of alginate at different mixing ratios and varying ionic strength.

For this purpose, zeta potential, turbidity and rheology measurements of single biopolymer solutions and their mixtures were conducted at pH 7. Alginate gelation was facilitated using calcium sulfate at a constant concentration. For the analysis of alginate gelation, a model mixing system consisting of 2-component cartridges with an attached static mixer was applied, which is commonly used in the mixing of 2-component adhesives.

Zeta potential measurements showed negative charges for both biopolymers, indicating repulsive interactions which lead to a phase separation as seen in the turbidity measurements. The developed method for mixing the alginate-pea protein suspension with the calcium solution enabled the characterization of the influence of the protein on the alginate gelation. Low contents of plant-based protein (weight fraction 0.05) delayed the alginate gelation and resulted in a lower gel strength. The negative effects of a high ionic strength on the alginate gel strength were not detectable when protein was added. In many cases, the addition of a low amount of a second biopolymer leads to a faster gelation due to a local concentration increase. These contrary results suggest a complex phase behavior of alginate and the protein, which strongly depends on the ionic strength and protein content. Further studies are needed to clarify the complex interactions of alginate, plant-based protein and calcium ions.

Acknowledgements: This IGF project (AiF 22232N) of the FEI is supported via AiF within the programme for promoting the Industrial Collective Research (IGF) of the German Ministry of Economics and Climate Action (BMWK), based on the resolution of the German Parliament.

The effect of protein-pectin interactions on curdling phenomena of soy drinks in cappuccino applications 31

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ABSTRACT

Milk alternatives, particularly soy-based beverages, often encounter an unappealing problem when introduced to coffee. This so-called curdling phenomenon is characterized by the formation of feather-like clumps resulting from protein aggregation and coagulation in the acidic, high-temperature environment of coffee. While stabilizers are commonly used as a coping mechanism, the use of pectin in the soy drink matrix remains an understudied aspect. This study investigated pectin's impact on curdling mitigation in two soy drink variants, i.e. drinks with and without added acidity regulator. Low methoxyl (LM) and high methoxyl (HM) pectin, with different degrees of esterification (DE), were added at concentrations of 0.1 %, 0.2 %, 0.4 %, and 0.8 %. The investigation evaluated curdling susceptibility through visual observations during an acid coffee test (at different pH conditions) and microscopic analysis of the curdled particles. The influence of the added acidity regulator was investigated via titration curves. Additionally, drinks' isoelectric point was determined through zeta-potential measurements as a function of pH, while important physicochemical attributes, including viscosity, frothability, and foam quality, were examined as well. The results demonstrated that the addition of 0.8% of either LM or HM pectin to both soy drink types notably reduced their curdling sensitivity, especially in soy drinks without an acidity regulator. The beneficial effect of pectin was attributed to electrostatic interactions between negatively charged pectin and positively charged soy proteins, giving rise to a decrease in the isoelectric point. Unexpectedly, the pectin type had a limited impact on curdling stability. However, HM pectin significantly influenced the viscosity, likely due to its higher molecular weight and efficient protein binding. This, in turn, led to a reduced frothability, as confirmed by microscopy. In conclusion, the addition of 0.8% pectin effectively reduced the curdling susceptibility in soy drinks for cappuccino applications and had a minor impact on their foaming properties.

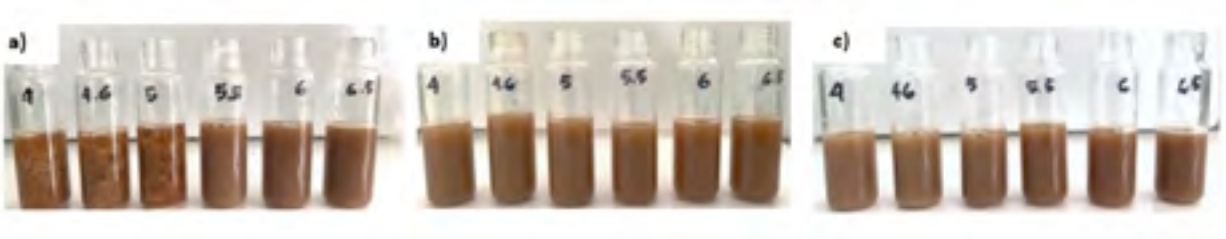

Figure 1. Acid coffee test results of soy drink without acidity regulator in the absence of pectin (a), and in the presence of 0.8% LM pectin (b), or 0.8% HM pectin (c)

Acknowledgments: The authors thank VLAIO (Flanders Innovation & Entrepreneurship) for funding the "Barista Project".

Commercial plant protein isolates: the effect of insoluble particles on gelation properties 36

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ABSTRACT

Commercial plant protein isolates generally contain a substantial fraction of large insoluble protein particles, caused by harsh processes during production. As a result, these materials have low solubility and have low functional properties. We studied the effect of these large insoluble particles on the properties of heat-induced protein gels (15% w/w protein, pH 7) and used homogenization as a mean to decrease the particle size.

Three commercial plant protein isolates were studied as model systems: Fava bean (FBPI), Pea (PPI) and Mung bean (MBPI). These isolates differed in protein source, particle size and amount of insoluble particles leading to differences in dispersibility. Homogenization (50MPa, 2 cycles) of plant protein dispersion reduced the particle size and improved the dry matter dispersibility of protein dispersions. However, treatment parameters and outcomes depended on the source and material properties.

We found that small and large shear deformation rheology (G' and breaking strain) were rather unaffected by homogenization in our protein gels. In contrast, fracture properties in uniaxial compression were sensitive to homogenization, with particle size reduction leading to gels that are more resistant to fracture. Gels obtained from FBPI, the isolate with the smallest fraction of insoluble particles and the only isolate containing native proteins, were the most fracture resistant.

Fluorescence microscopy revealed that the insoluble fraction remained well-dispersed in the matrix after heat-induced gelation, and that homogenization led to a more homogeneous appearance of the protein networks. We conclude that mechanically breaking down insoluble particles in commercial plant protein isolates contributes strongly to their functionality by reducing the number of large insoluble particles that act as effective nucleation points for hydrogel fracture.

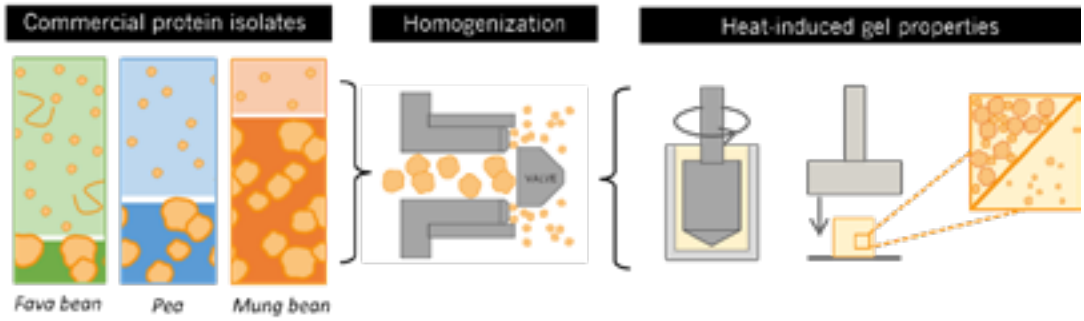

Figure 1. Study overview: Effect of homogenization on the gelation properties of three commercial plant protein isolates that differ in insoluble particle fraction

Novel plant-based bigel based on canola protein hydrogel and candelilla wax oleogel 65

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ABSTRACT

The increasing global population and growing demand for plant-based food alternatives have prompted the food industry to seek innovative food sources. The limited farmland, depletion of water resources, and rising food prices broaden this issue even further. The current research aims to explore a colloidal system that combines plant-protein-based hydrogel and wax crystal-based oleogel to develop novel food materials, such as alternative cheese, with enhanced nutrition and reduced environmental impact.

Various bigel formulations were prepared using a hot homogenization procedure at different compositions and preparation conditions. Canola protein was used in combination with transglutaminase (TG) to enhance the mechanical and rheological properties of the matrix through protein-protein chemical cross-linking. The effect of these parameters on the bigel mechanical, thermal, and structural properties was examined.

Various bigels were prepared, differing in enzyme concentration and oleogel:hydrogel (o:h) ratio, Figure 1, and their properties were analyzed. The addition of TG led to a stable and defined gel structure, while oleogel content produced bigels ranging from brittle with crumb formation at low ratio, to smooth and consistent texture, at high ratio. Confocal imaging revealed various bigel types and microstructures based on o:h ratios, with lower ratios forming oleogel in hydrogel bigel and higher ratios creating a bi-continuous system. Thermal stability and decomposition analyses displayed similar weight loss patterns, suggesting consistent decomposition behavior without dependence on the o:h ratio. Rheological behavior under shear and temperature fields revealed positive correlation between the storage modulus and angular frequency. Additionally, bigel behavior was sensitive to heating, with increasing temperature leading to a decrease in the storage modulus.

The results highlight the potential of plant-based bigels based on canola protein-TG hydrogel and candelilla wax oleogel as a versatile system for advancing alternative food applications.

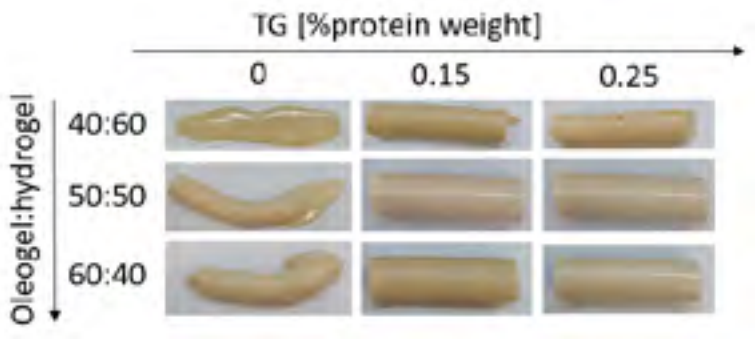

Figure 1. visual appearance of bigels at different oleogel/hydrogel ratio and enzyme concentration

Rubisco: an edible and functional protein applied in emulsions 75

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ABSTRACT

RuBisCo is the most abundant protein, which may be isolated from several sources like water lentils, alfalfa or sugar beet leaves.

The protein isolation process is constantly improved to maintain the protein's molecular structure and functionality for food applications. Its functionality is an emerging and growing research topic, showing promising characteristics for applications in gels and emulsions. However, little information about the protein characteristics like molecular structure, solubility depending on pH, as well as emulsion stabilisation mechanisms are known. The emulsions stabilisation mechansims are affecting the emulsion characteristics on a macroscale like oil droplet size, and on a microscale like interfacial properties.

Therefore, we investigated RuBisCo from different origin, and focused on properties of the protein and its emulsion on a macro- and microscale.

The results of both -macro- and microscale- complete the understanding of RuBisCo stabilized emulsions, while static light scattering and CLSM focuses on properties of the macroscale; drop tensiometry and interfacial viscoelasticity analyse the microscale; and SANS and SAXS cover the whole length scale range. The results indicate that RuBisCo is a promising protein source for food applications with interfaces.

Unlocking the physical-chemical aspects of roasting and sonication effects on flaxseed gum extract in O/W emulsion for a sustainable food systems 92

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ABSTRACT

The utilization of flaxseed cake in food applications offers a sustainable and innovative approach to reduce waste and enhance the nutritional profile of food products. Flaxseed cake, a by-product of flaxseed oil extraction, is rich in nutrients such as proteins, fibre, and lignans, making it an attractive raw material for the food industry. This research investigates the impact of roasting on the physical and chemical properties of flaxseed cake-extracted gum, along with the application of sonication techniques in oil-in-water (O/W) emulsions. The study underscores the crucial need for employing a variety of multidisciplinary analytical methods, including advanced chromatographic, confocal microscopic, colorimetric, and rheological tools. The secondary objective underscores the long-term potential of roasting and sonication in influencing the physical and chemical characteristics of the colloidal system, specifically oil-in-water emulsions. This is illustrated through shelf-life tests using the same analytical techniques. Regarding the physical aspects, the mean droplet diameter for roasted gum-stabilized emulsions (279±9.92 nm) was significantly smaller than the control sample (lecithin) (1030±38.41 nm). Interfacial tension, measured using the pendant drop method, demonstrated higher emulsion stability for roasted flaxseed cake-extracted gum (13.68±0.58 mN/m) compared to the control sample (15.34±0.99 mN/m). Additionally, the surface charge of this gum-based surfactant exhibited similar behaviour compared to the lecithin-based surfactant. On the chemical level, both roasting and sonication led to a significant decrease in primary (peroxide value) and secondary (volatile components) lipid oxidation products during both short and long-term storage periods. The combination of roasting and sonication techniques holds promise for improving the performance of these natural emulsifiers in O/W emulsions. This has the potential to replace synthetic emulsifiers, contributing to a more sustainable food production landscape.

Valorisation of Chickpea Aquafaba: Composition, Characterisation and Colloidal Properties of Natural Nanoparticles in Aquafaba for the Encapsulation of Chilli Oleoresins 108

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ABSTRACT

Aquafaba, a byproduct obtained from both canned and boiled raw chickpeas, is often disregarded as a food waste stream. Containing heat-denatured proteins, polysaccharides, and self-assembled incidental nanoparticles, aquafaba has the potential to replace animal-origin emulsifiers and synthetic surfactants. However, the occurrence of incidental nanoparticles formed during cooking and their potential role as an encapsulation and emulsifying agent for bioactive compounds such as capsaicin, the active alkaloid present in chilli peppers, remains unexplored. The aim of this study is to explore the composition of British Kabuli chickpea aquafaba, characterise its biophysical and techno-functional properties (**Figure 1**), assess its applicability to produce encapsulated capsaicin systems and evaluate the optimal stability conditions for these colloidal systems. The total carbohydrates (%), proteins (%), phenolics (mg/g) and saponins (mg/g) composition of aquafaba obtained by soaking (16 h, 4°C, 1:4 chickpea: soaking water) and cooking (20 min, 113°C, 10 psig, 1:5 chickpea: cooking water), were determined. The natural nanoparticles and denatured protein chains were characterised by DLS showing a bimodal size distribution (D_h ≤~1000 nm and D_h ≤~100 nm). Moreover, TEM imaging confirmed the presence of nanoparticles with a diameter size range from 12.5 nm to 71.4 nm. SAXS data revealed a radius of gyration (R_g) of ~9.6 nm, somewhat smaller compared to DLS and TEM results. Oil-in-water emulsions containing capsaicin oleoresins (1% v/v oil phase) were created using three types of chilli oleoresins (capsicum, chilli bird's eye, and chilli ancho) through high-pressure homogenisation and physical stability was monitored over the 28 days. We hypothesise that these systems are formed by the adsorption of the nanoparticles and proteins, leading to a Pickering system. Ongoing studies are seeking to obtain more stable systems, using an experimental design to establish the optimal composition and investigate their stability against environmental conditions such as pH, salt and temperature.

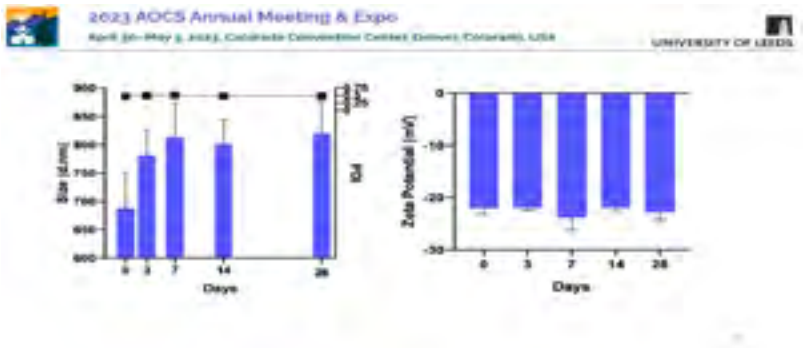

Figure 1. Evolution of the particle size, polydispersity (PDI) and ζ-potential of aquafaba during storage for 28 days at 4 °C

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Functionalization of pea protein by chemical modification as a gelling agent 112

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ABSTRACT

Food gels are viscoelastic systems used in the food industry to develop products with high water content, enhanced texture and taste, reduced calories, and as a carrier of bioactive compounds. These systems are mainly constituted by gelling compounds such as polysaccharides and proteins. Several plant proteins (mainly legumes) such as soybean, pea, and lentils, among others, have been used as alternatives for animal-derived due to their availability, low cost, and sustainability. Pea protein consists of legumin (11S), vicilin (7S), and albumins (2S) fractions, in major proportion 11S and 7S, like soybean protein. However, some functional properties in pea protein, like gelling, are limited (weak gels), and high concentrations are needed. It has been studied that the microstructure of proteins has an impact on the final functionality; thus, the modification of their structure has been a strategy to enhance or tailor protein properties. In this work, the effect of the structural modification of pea protein on some structural characteristics and gelling properties was studied. Pea protein was modified using a Maillard reaction with glucose sugar at -1, 0, and +1 (2, 4, and 6 hours of incubation). Samples were dialyzed and freeze-dried for further use. The FTIR spectrum showed changes in the amide II band and amide A due to the formation of cross-linked sugars (glycoconjugates). Lower denaturation temperature for level 0 (144 °C) compared to levels -1 (146 °C) and +1 (151°C) was found. The lower and higher modification had a positive effect on protein solubility (at pH values away from their isoelectric point); however, the intermedium-modified samples were not water soluble at any pH (3-7). The same behavior was found for the least gelation concentration endpoint (LGE); both degrees showed 6 % LGE, and no gel was formed for intermedium modification. Our results showed that minimal food-grade modification of pea protein efficiently enhanced gelling properties at lower concentrations than reported values for commercial products.

Acknowledgments: The authors thank the CONACyT for funding FOINS 4950 and the European Union's Horizon 2020 Research and Innovation Program under grant agreement No. 952594 (ERA Chair project DRIFT-FOOD).

Enhancing the Textural and Rheological Properties of Fermentation-induced Pea Protein Emulsion Gels with Transglutaminase 115

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ABSTRACT

The aim of this study was to assess how transglutaminase (TG) impacts the microstructure, texture, and rheological properties of fermentation-induced pea protein emulsion gels. Additionally, the study examined the influence of storage time on the functional properties. Fermented pea proteins were treated with and without TG and then stored for 1, 4, 8, 12, and 16 weeks. Texture analysis, rheological measurements, moisture content and microstructure evaluation with confocal laser scanning microscopy (CLSM) and 3D image analysis were conducted to explore the effects of TG on the structural and rheological properties of the fermented samples. The porosity of the protein networks in the pea gels decreased in the presence of TG, the storage modulus increased and the textural characteristics were significantly improved, resulting in harder and more springy gels. The gel porosity increased in gels with and without TG after storage but the effect of storage on textural and rheological properties was limited, indicating limited structural rearrangement once the fermentation-induced pea protein emulsion gels are formed. Greater coalescence was observed for oil droplets within the gel matrix after 16 weeks of storage in the absence of TG, consistent with these protein structures being weaker than the more structurally stable TG-treated gels. This study shows that TG treatment is a powerful tool to enhance the textural and rheological properties of fermentation-induced pea protein emulsion gels.

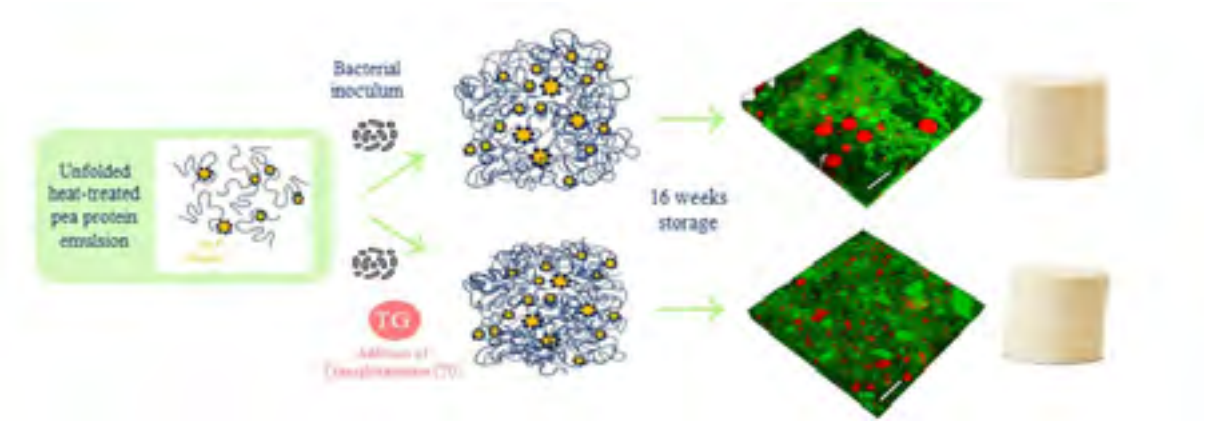

Figure 1. Schematic description of the production of fermentation-induced pea protein gels with and without transglutaminase.

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Effect of acid hydrolysis on pectin extraction and films developed from apple juice processing by-products 120

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ABSTRACT

Pectin is an effective biopolymer for fabricating edible films due to its properties (excellent gel-forming ability, biodegradability, and biocompatibility). Commercial citrus and apple pectins have been used to develop edible coating materials. In this study, pectin obtained using three different acids: a) hydrochloric acid (HA), b) citric acid (CA), and c) Glucono Delta-Lactone (GDL) was partially characterized and used to produce edible films (2% pectin, 1.5% glycerol). The effect of acid type on the pectin yield, color, and rheological properties was studied and compared to commercial citrus pectin (CCP) and commercial apple pectin (CAP). Results showed that CA acid had the highest pectin yield (12 %), followed by the GDL (7.64 %) and the HCl (7.44 %). A lighter color was observed for CA pectin (74.12 ± 0.28) than other samples; in contrast, it was observed that HCl acid gave rise to a dark-brown color (51.44 ± 0.40). Chroma values of CA pectin (35.00 ± 0.06) were similar to GDL and HCl samples (35.70 ± 0.15 and 35.97 ± 0.17, respectively). In terms of color values, similar behavior occurred for edible films. CA pectin edible films showed the lowest strength values (0.38 ± 0.02), and GDL and CA pectin edible films behaved similarly (0.71 ± 0.02 and 0.72 ± 0.02 N, respectively). Regarding the rheological properties, higher viscosity values (even than commercial samples) were observed for GDL pectin-calcium solutions (1,295 m.Pa.s) followed by HCl (134 m.Pa.s) and CA (108 m.Pa.s). Our results showed that extraction methods could affect the properties of the pectin obtained and the edible films prepared. As a result, GDL pectin edible films were more comparable than both commercial pectin-based edible films.

Acknowledgements: This research was funded by European Union's Horizon 2020 Research and Innovation Program under grant agreement No. 952594 (ERA Chair project DRIFT-FOOD).

Jellyfish biomatrix: A novel multi-functional food stabilizer 122

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ABSTRACT

Jellyfish have recently been suggested as a sustainable source of bioactive compounds. However, their potential as a food stabilizer and culinary ingredient remains largely unexplored. This study examines for the first time the multi-functional stabilizer potential of the jellyfish biomatrix, and reveals its interesting structuring properties for emulsions, oleogels, gels, and foams [1].

The study adopts a top-down approach by employing a stepwise refinement in the extraction of the jellyfish biomatrix. Two distinct jellyfish biomatrix powders are examined: the native biomatrix, preserving the composition of intact jellyfish dry matter, and the desalted biomatrix with reduced salt content. The primary focus of this study centers on the emulsifying properties of the two biomatrices. In the effort to unravel the nuanced emulsifying properties, we have employed a combination of rheological analysis, modern label-free microscopy (Coherent Anti-Stokes Raman Scattering microscopy), and state-of-the-art image analysis for quantitative assessment of jellyfish-based emulsions.

The results demonstrate enhanced emulsifying properties of desalted jellyfish biomatrix compared to the native jellyfish powder. Despite the relatively poor emulsifying properties of native jellyfish emulsions and the presence of Ostwald ripening, these emulsions experience an increase in storage modulus during storage. This facilitates that native jellyfish emulsions can act as a template for oleogelation upon water evaporation, which not were possible for desalted jellyfish emulsions.

Moreover, jellyfish biomatrix demonstrated lubrication trends that might carry the potential to provide advantages in the formulation of sustainable food matrices, potentially mitigating the astringency often associated with plant-based food stabilizer alternatives.

This study highlights the value of employing quantitative image analysis in the assessment of emulsions and simultaneously emphasizes the potential of the underutilized jellyfish biomatrix as a promising alternative food stabilizer.

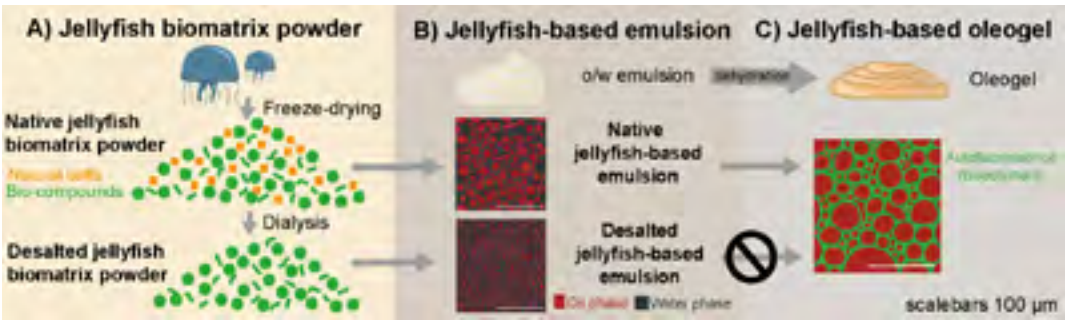

Figure 1. Jellyfish biomatrix as a stabilizer. A) Two distinct powders are examined. B) Image analysis is employed for quantitative assessment of emulsions. C) Native jellyfish emulsion can act as a template for oleogelation.

References: [1] Pedersen et al., Jellyfish as food stabilizer, EP22196368.9, Patent pending.

Acknowledgements: The imaging facility DaMBIC (Novo Nordisk Foundation, NNF18SA0032928), and the Velux Foundations (Villum25414).

Triumfetta cordifolia gum: a plant-based hydrocolloid with an interesting potential in the formation and stabilization of oil-in-water emulsions 130

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ABSTRACT

Many industries such as foods are searching for efficient and sustainable surfactants capable of stabilizing emulsions or colloidal dispersions (thermodynamically unstable). However, conventional surfactants are often subject of many controversies such as their petroleum origin and environmental concerns. Therefore, the search for new - natural, biocompatible, environmentally-friendly, available, competitive - surfactants is a real challenge today. This study aims to valorize a natural gum from *Triumfetta cordifolia* (a food colloid used in African cooking to make sticky sauces) as a sustainable emulsifier and stabilizer for oil-in-water (O/W) emulsions. To this end, the gum was first characterized in aqueous solutions by surface tension and viscosity measurements. Then, emulsions were prepared at room temperature according to an experimental design involving three oils of different polarities (low, medium and high) and two gum concentrations (0.2% and 0.4% w/w). Resulting mixtures were characterized and monitored over time using optical microscopy, laser granulometry, static multiple light scattering, rheology and pH measurements. The results revealed interesting surface properties, such as the ability to decrease water surface tension to 42.9±1.1 mNm^{-1} for a gum concentration of only 0.2% w/w. Stable O/W emulsions were obtained by simply adding *T. cordifolia* gum as a third ingredient in oil-water mixtures (figure 1). The best results were observed with cocoglyceride oil due to its stronger effect of lowering interfacial tension thus acting as a co-emulsifier[1] but an increase in gum concentration enhanced system stability (beyond 31 days at 20 °C). Overall, this research has demonstrated that intrinsic properties of *T. cordifolia* gum including surface activity, viscosifying capacity, and polyelectrolyte nature are responsible for its potential in O/W emulsions through the synergy of three mechanisms, including electrostatic, steric and viscosity-induced stabilizations[2]. Such findings undoubtedly show that *T.cordifolia* gum is a highly promising new bio-sourced and environmentally-friendly emulsifier/stabilizer for many applications including foods.

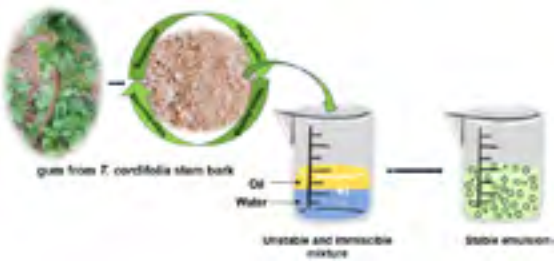

Figure 1. Illustration of emulsifying and stabilizing properties of *T. cordifolia* gum

References: [1] Fanwa et al. (2023). *Triumfetta cordifolia* Gum as a Promising Bio-Ingredient to Stabilize Emulsions with Potentials in Cosmetics. *Polymers, 15,* 2828. https://doi.org/0.3390/polym15132828

[2] Fanwa et al. (xxx). Understanding the unique potential of *Triumfetta cordifolia* gum in the formation and stabilization of oil-in-water emulsions. To be published.

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pH and salt dependent complexation between rapeseed cruciferin and napin 140

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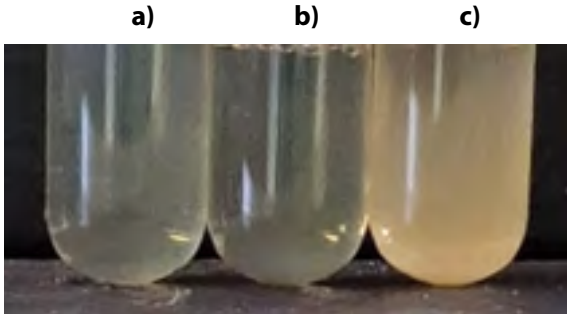
ABSTRACT

Plant proteins are increasingly in demand due to their lower environmental impact compared to animal proteins. Numerous researches have focused on integrating plant proteins into various food products. The present study concerns rapeseed proteins, also called canola, with a particular emphasis on the two principal protein components: a globulin called cruciferin and an albumin called napin. Cruciferin is negatively charged above its isoelectric point of about pH 6, whereas napin is positively charged below pH 11. Strong electrostatic interactions are therefore expected between the two components above pH 6. The main objective of the present study was to explore the interaction between these two proteins by mixing them in aqueous solution in different ratios at different pH.

In pure water, complexation between these two proteins was indeed observed at pH ≥ 8 leading to the formation of large aggregates that sedimented during centrifugation even though both individual components were fully soluble in this pH range. At pH ≤ 6 cruciferin was only partially soluble and did not interact with the fully soluble napin. At pH 7 both insoluble cruciferin and complex formation were observed. Surprisingly, in the presence of 0.1M NaCl the protein mixtures remained soluble at pH 8 forming only very small aggregates even though cruciferin by itself is only partially soluble at pH 8 in the presence of salt. In fact, insoluble complexes formed in pure water could be solubilized by adding salt by dissociation of large complexes, see figure. We will discuss the effect of the ratio between cruciferin and napin on the extent of complexation and their composition at different pH. These findings are important for a better understanding of the behaviour of mixtures of napin and cruciferin in rapeseed protein isolates.



Mixure Napin and cruciferin 50/50 wt%, (a) adding 0.1M NaCl before mixing, (b) adding 0.1M salt on the mixture (c) without salt

Heat-induced aggregation and gelation of rapeseed cruciferin and napin: Effect of heat treatment as function of pH, ionic strength and concentration 141

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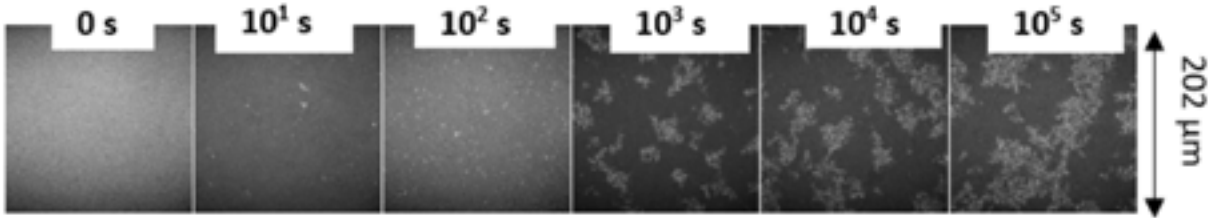
ABSTRACT

In an effort to improve sustainability and minimise the impact on the environment, there is a growing interest to replace animal protein by plant protein for human consumption. An auspicious source of plant protein is rapeseed that is already grown extensively to produce oil. Currently, rapeseed is used to produce edible oil and the remainder is used as animal feed or discarded. The discarded waste contains significant amounts of protein that can be useful for human consumption and it is the aim of this study to valorize the rapeseed protein. We investigated techno-functionality and structure to better understand rheological behaviour and properties of rapeseed such as the effect of heat treatment on its aggregation as function of the pH, ionic strength and concentration, which can help in formulation of new product in food industries.

Commercialised rapeseed protein isolate (RPI) and purified samples of the principle protein components i.e. napin and cruciferin as well as their mixtures, were investigated. Confocal microscopy showed that RPI micro-particles were formed that subsequently aggregated and these aggregates can form a gel over time if the concentration is sufficiently large. RPI formed weak heat-induced gels that were heterogeneous and had a tendency to show some syneresis. In this presentation we will show the important effects the temperature, pH, protein concentration and protein composition on this process, utilizing several characterization methods such as microscopy, light scattering, rheology and electrophoresis.



Formation of particles with a diameter of about 1 µm followed by growing aggregates which precipitates over time, T = 50°C

Air bubble powders for use in foods 145

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ABSTRACT

Micron- and submicron sized air bubbles have many potential applications in foods, such as texturing agent, fat replacers, and also opacifiers (or "whiteners"), due to their strong light scattering. We are expanding on a known approach for making bubble powders via the drying of oil in water (O/W) Pickering emulsions, where the oil is volatile. Current formulations call for ingredients that food producers might want to avoid such as silica nanoparticles and cyclooctane as a processing aid. Our goal is eventually produce air bubbles with enhanced stability in food matrices, using ingredients more acceptable to the food industry, such as more natural volatile oils, and food-approved hydrophobic nanoparticles (FAHN).

First, concerning stability, we report on a novel formulation with hydrophobic silica nanoparticle stabilizers present in both the water and oil phase. We observed that this leads to air bubbles with a porous particle network inside. These "network" bubbles also remain more stable than "single layer" bubbles. The network bubbles are also stable in fava-bean protein dispersion and have a significant whitening effect on these dispersions. Next we also showed that we can replace the hydrophobic silica nanoparticles with the preferred ingredient of FAHN. We confirm that this also leads to very stable bubbles with stabilities in both water and fava-bean protein dispersions of up to four weeks. In our ongoing work, we aim to 1) further reduce the size of the microbubbles (creating submicron air bubbles) to achieve a more pronounced whitening effect, and 2) explore the use of more natural volatile oils to replace the cyclooctane as a processing aid.

Beyond their application in food products, we believe biobased air bubble powders could have many other applications, such as general (biobased) product aeration, or as replacements for Titanium Dioxide in wall paints.

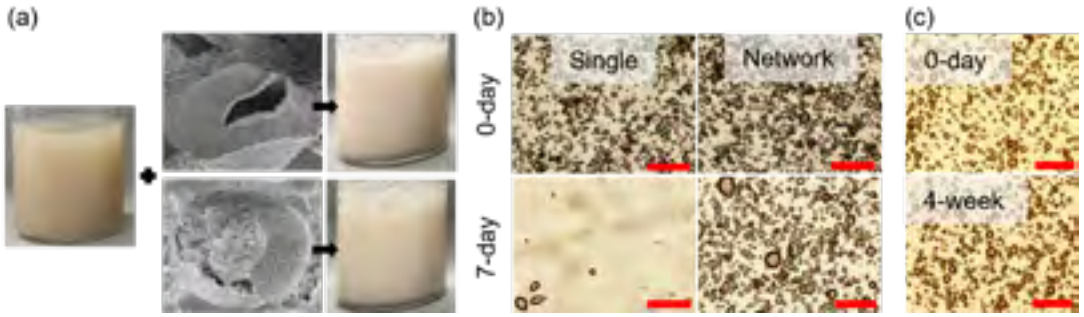

Figure 1. Whitening effect and qualitative stability of silica and FAHN microbubbles. (a) fava-bean protein solution with/ without silica microbubbles. (b) Silica microbubbles: optical images in water over 1 week. (c) FAHN microbubbles: optical images in water over 4 weeks. Scale bars are 100 µm.

Acknowledgements: This research is supported by the Chinese Scholarship Council (CSC).

Protein functionality in high-protein plant-based cheese 168

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ABSTRACT

Waxy starch, plant-protein isolates, and coconut oil were combined to create a novel high-protein (18w/w) plant-based cheese. We determined that by using native waxy starch, we can enhance its existing viscoelastic properties by modulating gelatinization through the addition of plant protein and fat. Plant protein isolates were assessed for their functional properties where low solubility, low emulsification capacity, and greater water-holding capacity correlated with low surface-active proteins. The opposite; high solubility, high emulsification capacity and lower water holding correlated to greater surface activity. Upon assessing the proteins in our cheese formulation it was determined that low surface active proteins resulted in cheeses with superior sample melt and stretch reaching 2-4times greater than those observed for commercial plant-based cheeses. Whereas, high surface active proteins resulted in cheese with little to no melt or stretch. The rheological melting curves showed that samples with low surface active protein exhibited a significant decrease in the Storage modulus (G') between 40-80°C, indicating that the starch had undergone better gelatinization, leading to the loss of structure. On the other hand, samples with high surface-active proteins did not experience the same extent of G' decrease and, instead, maintained a more solid structure with less softening of the sample. FTIR spectromicroscopy of the cheese systems identified that low surface active protein behaved as a particulate filler with starch making up the majority of the cheese structure thus allowing the starch to stay connected but have the proteins act as junction points to aid in sample breakdown when heated. Whereas with high surface active protein, FTIR identified that the protein acted as the main structural matrix thus limiting the softening and melting of the cheese product. Ultimately by focusing on the functional properties of the proteins and utilizing the characteristics to modify foods, it is possible to have superior product performance.

Acknowledgements: The research was financially supported by the Natural Sciences and Engineering Research Council of Canada (NSERC)

Impact of protein properties on the functionality of plant-based cheeses formulated with saturated and unsaturated fat 189

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ABSTRACT

Plant-based cheeses offer a more environmentally friendly alternative to traditional dairy cheese. Coconut oil, high in saturated fat, is often incorporated to mimic the structure and texture of animal fat. Addressing health and sustainability concerns through alternative fat combinations in plant-based foods is critical. The influence of protein properties on the functionality of plant-based cheeses formulated with saturated and unsaturated fats was investigated through protein properties such as solubility, as well as the functionality of the cheese through hardness, melt, and rheological analysis. Cheeses were made with three different pea proteins (PP1, PP2, PP3), a faba protein (FP1), and a lentil protein (LP1). The effects of saturated fat content on plant-based cheese physical characteristics were evaluated through five different ratios of coconut oil:sunflower oil (100%, 75%, 50%, 25%, and 0%). As determined through textural profile analysis, the hardness of the cheeses after setting at 5°C for 24 hours increased with increasing amounts of coconut oil due to the additional firmness related to the additional solid fat content. However, PP1 was the only protein at 25% coconut oil that produced cheese with a hardness of over 65N, which is similar to the hardness of 68N at 75%. This implies that there are interactions between this specific protein and fat blend, causing this greater hardness compared to the cheeses made with other proteins. The cheeses' rheological properties were determined between 20-95°C. The evaluation focused on the tanδ (ratio of loss modulus to storage modulus) value at 95°C as a metric for measuring cheese melt, with values nearing 1 signifying a more optimal melting performance. Although the hardness of the PP1 cheese was 30N harder than the other cheeses, it still maintained a similar melt and stretch, as well as a tanδ value within 25% of the other cheeses. These results show an opportunity to tailor protein-fat interactions to achieve the desired hardness while maintaining good functional properties and improving the sustainability and health benefits of the final product.

Acknowledgements: This research was financially supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) and Daiya Foods (Burnaby, BC, Canada).

Improvements on the Functionality of Native Legume Starch Gels Through Amylose-Lipid Complexation 192

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ABSTRACT

The process of isolating protein from pulse sources can result in the production of starch as a by-product. Starch derived from pulse sources often contains high levels of amylose, which can lead to the formation of brittle retrograded gels. An effective approach to enhancing the performance of these gels is through the formation of amylose-lipid complexes. Native pea, fava bean and chickpea starches containing 25-30% amylose were complexed with stearic (SA), oleic (OA) and capric acid (CA) as well as glycerol monostearate (GMS) and glyceryl monopalmitate (GMP) in order to deduce any functional benefits associated with amylose-lipid complexation.

Complexation of all the native starches with SA, CA, GMS and GMP at 5%, 7.5%, 10% and 12.5% (w/w; lipid/dry weight of starch) levels significantly reduced the hardness in 10% (w/v; dry weight of starch/water) retrograded gels, as determined by Texture Profile Analysis. The retrograded complexes also showed decreased adhesiveness and cohesiveness. These parameters further suggest that SA, CA, GMS and GMP interact with amylose, decreasing its brittleness. Dynamic oscillatory rheological analysis in showed that the complexed starches had significantly lower storage modulii (G') compared to the native starches ($P<0.05$). The associated stress-strain curves also demonstrated improved strain softening, displaying more plastic-like profiles and decreased shear stress values at the yield points for the complexed samples. Interestingly, the complexed samples show decreases in their linear viscoelastic regions and slightly lower yield points in comparison to the native starches. Wide angle X-Ray Diffraction suggests that complexation of the native starches with fatty acids and monoglycerides changes the crystal morphology of the samples from B-type amylose crystals to V_h-Type amylose crystals. Overall, this research demonstrated that amylose lipid complexation may be a useful tool in modifying the mechanical and rheological properties of legume starches.

Acknowledgements: The authors would like to thank Daiya Foods Inc. (Burnaby, BC, Canada), the Natural Sciences and Engineering Research Council of Canada (NSERC), and the University of Guelph for financial support.

Correlating physicochemical properties of pea hull dietary fiber and pea protein blends to their in vitro fecal fermentation 200

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ABSTRACT

A healthy and sustainable diet includes plant-based or plant-derived proteins and intake of dietary fibre. Field pea (Pisum Sativum L.) consists of 20-30% protein and 15-25% dietary fibres, making peas interesting due to its high nutritional values. Another aspect is the possibility to grow peas in temperate climates, which is not possible for e.g., soy. We aim to characterize the physicochemical properties of pea hull dietary fiber and pea protein blends as a function of thermal processing and correlate them to their microbial fermentation products after batch in vitro fermentation with human faecal microbiota.

Chemical composition of pea polysaccharides was examined through hydrolysis of fibers followed by monosaccharide analysis. Rheological properties, such as viscosity, storage- and loss modulus were performed at different temperature and pH to understand the behaviour of the polysaccharide suspensions. Confocal laser scanning microscopy (CLSM) and light microscopy (Figure 1) was used to identify swelling of pea hull fiber and pea protein after thermal processing, as well as visualising the microstructure of the fiber. In vitro faecal fermentation of pea fiber-protein blends resulted in a more diverse SCFA composition compared to fermentation of pure fiber and protein. The presence of fiber indicated a lower accumulation of ammonia produced from protein fermentation. Future studies include further functionalization of pea hull fiber.

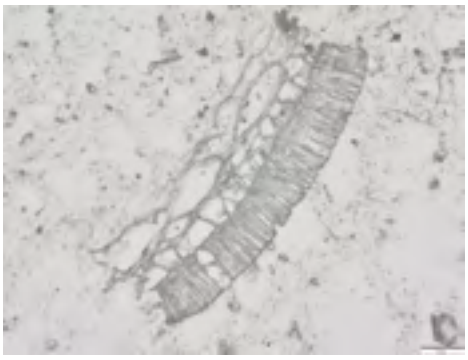

Figure 1. Light microscopy image of pea hull polysaccharide before in vitro faecal fermentation. Scale bar 50 µm.

Lipid oxidation and co-oxidation reactions in oleosome dispersions from various sources: Which constituents are involved? 202

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ABSTRACT

Oleosomes or oil bodies (OB) are promising ingredients for human nutrition due to their richness in polyunsaturated fatty acids and antioxidants, as well as their claimed high oxidative stability. This work analyzed the oxidative stability of three different fractions prepared via the extraction of OB from high oleic sunflower, rape, and chia seeds. Seeds were ground in water to liberate the OB as a natural ('total') emulsion. After filtration on a cheesecloth and centrifugation, an OB cream, an intermediate aqueous phase, and a pellet were collected. The total emulsion and OB cream were redispersed in water to yield 4 wt.% lipids. Upon incubation, oxygen consumption in the tubes' headspace was measured. Washed OB suspensions hardly showed oxygen consumption, except for the chia OB after day 5. Conversely, extensive oxygen consumption occurred rapidly in total emulsions, showing that these systems are prone to oxidation (Figure 1A). Yet, when measuring lipid oxidation markers, low levels were found. This suggests that oxygen is consumed by other reactions. Proteins can also be targeted by oxidation; however, the fluorescence of tryptophan was not affected in the different samples (Figure 1B, red arrow). The 3D fluorescence spectra allowed the detection of other fluorophores, likely corresponding to phenolic compounds, of which the fluorescence intensity seemed to be somewhat quenched upon incubation (Figure 1B, yellow arrow). This may indicate that phenolic compounds, present in the total emulsion (and in the aqueous phase + pellet) but largely eliminated in the OB suspensions, substantially oxidized. This is consistent with the visual browning of the samples upon incubation, which looked well aligned with the extend of the oxygen consumption (Figure 1C). These results confirm that OB overall exhibit a good resistance to lipid oxidation, apparently targeting the non-OB constituents of oilseeds. Further investigations of the substrates and reactions involved are ongoing.

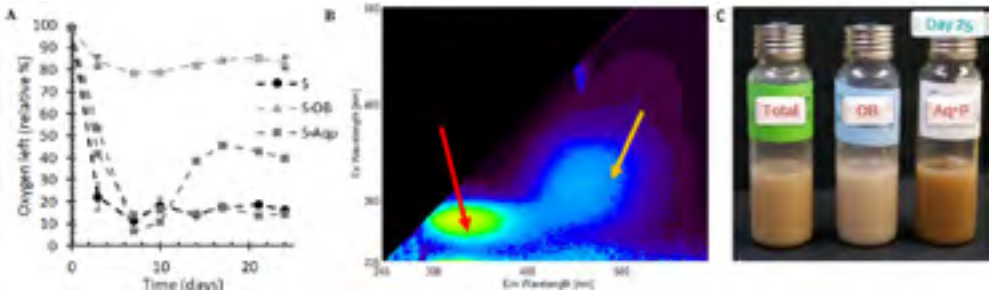

Figure 1. (A) Oxygen consumption of high oleic sunflower (S) systems over time (OB = re-dispersed oleosome cream, Aqp = aqueous + pellet phase), (B) 3D fluorescence excitation-emission matrix of rapeseed total emulsion (red arrow = protein fluorescence, yellow arrow = hypothesized phenolic compounds fluorescence), (C) visual browning of samples stored at 25°C.

The financial support of this work by the Carnot institutes Qualiment and 3BCAR (OBEINN project) is gratefully acknowledged.

Synergic interaction between chitosan and peptides from shrimp side-streams (Pandalus borealis) before and after pulsed electric field treatment 203

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ABSTRACT

Aim of the research: Even though shrimp byproducts have shown interesting bioactive components, such as chitin, proteins/enzymes, pigments, and lipids, most of these byproducts are discarded. Herein we aimed to evaluate the interaction between chitosan and peptides from shrimp, before and after pulsed electric field treatment to further explore the emulsifying property.

Material & Methods: Protein hydrolysis was applied using Trypsin 0.5% (E/S). Chitosan was obtained with a 80% (FTIR method) degree of deacetylation using ultrasound during the synthesis; Supramolecular chitosan/peptides complexes were formed at two different pHs 6.2 and 4.2, and their emulsifying properties were evaluated. Samples were characterized by Differential Scanning calorimetry (DSC), Fast Protein Liquid Chromatography (FPLC) and Size Exclusion Chromatography Coupled to Multi-Angle light Scattering (SEC-MALS). The emulsion stability was verified by Turbiscan method (TSI value), and the interfacial properties and viscosity were studied by double wall ring rheology and bulk rheology, respectively. Confocal Laser Scanning macroscope (CLSM) and cryo-TEM microscopy techniques were applied.

Results & Discussion: Emulsion stability was significantly improved in the presence of chitosan/peptides, and even higher when PEF was applied. Microscopy techniques revealed a cluster formation when proteins and chitosan were used as emulsifier whereas in presence of chitosan no aggregates or clusters were evident. The formation of cluster entrapped the oil droplets and increased the viscosity. Interfacial rheology also revealed a faster solid/film formation on the oil/water interface and a higher value of storage modules when Chitosan/protein and PEF was used.

Conclusion: The study highlighted the potential functionalities of shrimp side-stream and the positive impact of pulsed electric filed in the valorization of these components when aimed to be applied as alternative emulsifiers.

Comparative study of solubility and oil-water interface properties of laboratory and commercial pea protein isolates (PPIs) with pH-shifting treatments 210

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ABSTRACT

Pea protein isolates, a kind of green and cheap plant protein, have great potential in food industry, like being the emulsifier and foaming reagents. However, the poor solubility of PPI in water limits its applications. pH-shifting treatment has been proved to improve the solubility and emulsifying capacity of pea protein isolates [1]. A comparative study was conducted on commercial PPIs (namely Roquette) and lab-scale PPIs (prepared by alkaline extraction and acid precipitation method), the initial chemical composition (including total protein, total lipid, ash, moisture and starch content) and protein subunits composition (analyzed by polyacrylamide gel electrophoresis and size exclusion chromatography-high performance liquid chromatography) was compared. Besides, pH-shifting can be regarded as an effective way to increase the solubility of both commercial PPIs and lab-scale PPIs. Lab-scale PPIs got 80% protein solubility under mild alkaline pH-shifting treatment (pH=8.0), while commercial PPIs reached the same protein solubility under extreme alkaline pH-shifting treatment (pH=12.0). Apart from that, coarse emulsions stabilized by both commercial PPIs and lab-scale PPIs were prepared and analyzed. The results illustrated that lab-scale PPIs had batter emulsifying properties than commercial PPIs: emulsions stabilized by lab-scale PPIs showed higher absolute value in zeta-potential, smaller particle distribution and better physical emulsion stability.

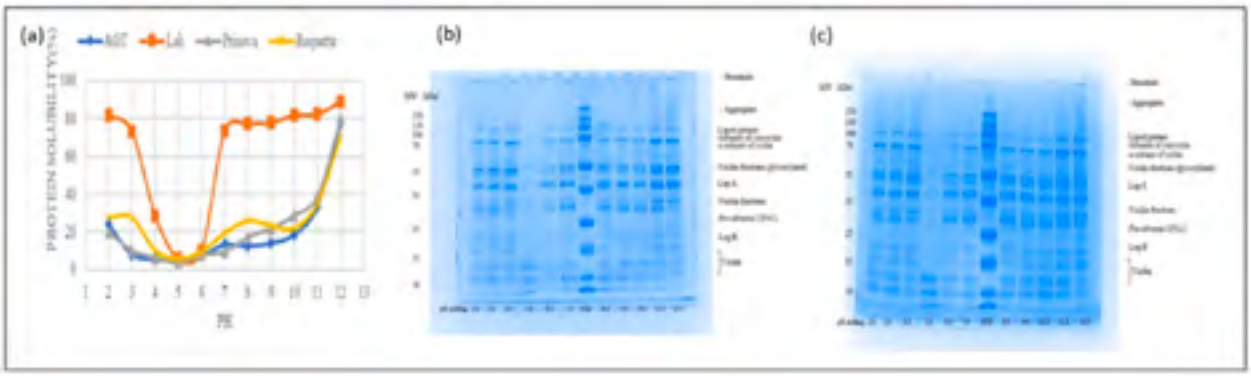

Figure 1(a). The effect of pH-shifting on the solubility (in percentage) of lab-scale PPI and commercial PPIs (AGT, Prinova and Roquette) in dispersions containing 1% (w/v) of PPI.

Figure 1(b) & (c). Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) profiles of pH-shifting treated lab-scale pea protein isolate samples (b) and commercial pea protein isolate (Roquette) samples (c) as well as the protein molar mass standard mix (STD) under reducing conditions.

References: Zhi, Z., Yan, L., Li, H., Dewettinck, K., Van der Meeren, P., Liu, R., & Van Bockstaele, F. (2022). A combined approach for modifying pea protein isolate to greatly improve its solubility and emulsifying stability. Food Chemistry, 380, 131832.

Acknowledgements: The research was supported by the Chinese Scholarship Council and Puratos (Thailand) Company Limited.

Incorporation of levant extracts into dairy model products 212

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ABSTRACT

This work presents the incorporation of levant extracts into models of dairy products, more specifically model cheeses formulated as whey protein isolate and/or sodium caseinate compressed aggregates. The incorporation of the levant extracts as function of the protein composition is reported, along with results on the effect of the extracts on the mechanical strength and the color of the cheeses. The above are discussed in relation to the structure of the products studied using NMR water mobility measurements and confocal microscopy. A critical evaluation of the resulting incorporation of levant extracts into model cheeses follows, focused on the valorisation of levant, and the functionalisation of cheeses.

Acknowledgement: We acknowledge support of this work by Project «Production and incorporation of levant extracts in milk products» (M16-SYN2-00065), funded under Sub-Measure 16.1 - 16.2 - Establishment and operation of operational teams of the EIP for agricultural productivity and sustainability - Agricultural Development Program 2014–2020.

Moringa oleifera proteins as pickering stabilizers in food emuslions 215

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ABSTRACT

Substantial food waste as a result of chemical decay of food enormously impacts the environment, henceforth need of stabilization by surfactants but the associated carbon footprints possess a threat for the industry. Thus, Pickering emulsions, stabilized by solid- particles, residing at droplet interfaces comes into the picture, providing more stable systems than surfactants. In terms of resistance against fusion (coalescence) and coarsening (Ostwald ripening) Pickering emulsions are thermodynamically stable systems with good biocompatibility and can be utilized as carriers for delivery of bioactive compounds, thus applied in food to control and enhance texture and taste and improve stability[1]. Plant proteins attract great interest and the stability of Pickering emulsions is governed by protein properties, protein concentration and environmental factors. The Moringa protein has been chosen, because it is inexpensive, with great nutritional benefits and wide availability and has been scientifically proven to have excellent anti-oxidant, anti-hypertensive and anti-diabetic properties.

Protein particle interactions are very much dependent on pH. Such protein- based nanoparticles have proven to be advantageous as they are biodegradable, non-toxic, and provide large possibility for surface modification. All this motivates our study to investigate the Moringa protein as Pickering particles for emulsions fabricated at different pH and ionic strengths. The rheology and corresponding macroscopic gel properties of such emulsions can be designed by arrested coalescence for producing food spreads with desired rheological properties[2]. During this, aggregates are formed with interaction between denatured non-absorbed proteins and absorbed ones at the emulsion droplet interfaces which can be impact of lipid oxidation, which influence emulsion particle interactions. Proteins can form gels after aggregation at different pH or ionic concentration. 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 distinguish the "good" and "not so good" Moringa based protein stabilizers by utilizing microscopic observations and rheometry and using Small- Angle -X- ray-Scattering (SAXS) to examine structural stability and aggregations of the same stabilizing proteins, thus gathering information on protein[3], and how this is connected to the rheological properties. Further works include formulating food spread using this emulsion and study its smell and mouthfeel quantification.

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Spirulina as a sustainable protein source of oil in water chickpea formulations 218

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ABSTRACT

The usage of algae as an alternative protein source, including micro and macroalgae, has been widely exploited worldwide; this path focuses on the European Union (EU) guidelines. The European Commission (EC) has supported algae as a source of alternative protein since 1997 for more sustainable food systems, global food security, cosmetics, pharmaceutics, and energy production. Spirulina (Arthrospira platensis) is a filamentous cyanobacterium with a blue-green color, popularly known as microalgae. The scientific exploitation of Spirulina is justified because of its high nutritional value as a source of alternative proteins and a variety of photosynthetic pigments (food colorants), such as β-carotene, lutein, and phycobiliproteins, which are represented by C-allophycocyanin, C-phycoerythrin and the most abundant and essential of them C-phycocyanin (C-PC). This work aimed to develop a vegan oil-in-water emulsion containing Spirulina (EMSB), presenting good physicochemical and nutritional properties as the control (EMCo). The analysis was performed to obtain the formulations' rheological and texture parameters, pH, color, and antioxidant capacity. EMSB was developed with similar characteristics of control (EMCo). Spirulina's antioxidant potential and phenolic compound addition in oil-in-water formulations were improved compared to EMCo. The color of the samples was maintained during 30 days of storage. The authors expected this work to draw researchers' attention to under-explored ingredients such as SB, FP, and NP with new technological approaches. This was a baseline study to understand the behavior of Spirulina biomass to new food development.

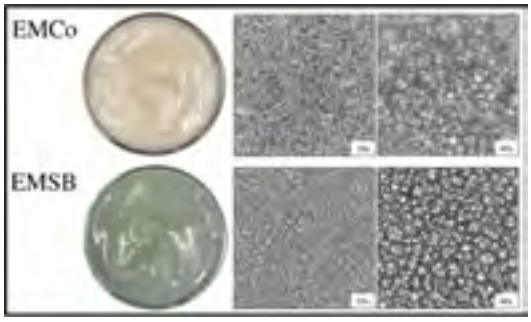

Figure 1. Oil-in-water formulations and microscopy (Leitz-Dialux Leica 20 – Portugal) representative images prepared without (EMCo) or with the incorporation of 0.5% of *Spirulina* (EMSB)

Acknowledgements: This work was financially supported by "Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES)" through the scholarship process nº 88887.364166/2019-00. This study was also supported by "Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP", through the grants process nº 2023/00857-0, 2022/06293-9 e 2020/06732-7.

Effects of different anti-freezing agents on ice crystal size and physical properties of low sugar ice cream 223

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ABSTRACT

Ice cream is a popular dairy product, and usually contains a lot of sugar. Due to the negative health effects, the development of low-sugar ice creams is desired. This can be achieved by using different anti-freeze agents, such as lower molecular weight sugars, sugar alcohols, salt, and protein hydrolysates. However, the replacement of sucrose will have a great effect on the structure and physical properties of the ice cream. We aimed to understand the role of anti-freezing agents in the structure development of ice cream (ice content, ice crystal formation, viscosity), and link different structural features to texture attributes and melting behavior.

To characterize the ice curve, we first determined the hydration number of anti-freezing agents, which, in frozen solutions, was negatively correlated with concentration and positively correlated with molecular weight. In the model ice cream without fat, anti-freeze agents that were able to increase viscosity to a larger extent resulted in smaller ice crystals. Ice cream with smaller ice crystals was harder and showed a slower melting process due to increases in ice crystals connectivity. As the studied protein hydrolysates contained both long peptides and short peptides, they were found to effectively control the freezing point and ice content, increase viscosity and positively impact overrun. To confirm the effects of hydrolysates in complex systems, we investigated ice cream recipes containing fat. The fat addition resulted in smaller ice crystals and a more homogenous distribution of their size compared to a reference sample containing sucrose. The melting behavior of protein hydrolysates samples was similar to that of the reference with sucrose, showing that they have the potential to replace sugar.

Overall, our study shows that the studied anti-freezing agents control both the structural and physical features of ice cream, and are of relevance for the formulation of low-sugar ice cream.

Polysaccharide/zein/PEO electrospun fibers to simulate the fibrillar structure for meat analogs 226

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ABSTRACT

The search for sustainability has increased interest in plant proteins that can replace animal meat while maintaining appearance, texture, and flavor. However, there is a significant gap in the market for meat analog products as it is difficult to accurately imitate the characteristic orientation of meat (fibrillar structure). To meet this need to maintain the appearance of animal meat in plant-based products, the electrospinning technique has been highlighted for producing fibrous materials. In this context, polymeric compositions of zein/polysaccharide/poly(ethylene oxide) (PEO) were tested in different proportions to produce fibrous structures for fish meat analogs. Three polysaccharides were investigated: alginate, carrageenan, and two varieties of pectin with two different PEO concentrations, 1 and 0.3 wt%. The zein/polysaccharide proportions tested were 90:10, 85:15, and 80:20 with a voltage of 24 kV and a feeding rate of 2000 µL/h. The results showed that the mixture of polysaccharide/zein/PEO (1 wt %) improves the processing of polysaccharides since, in all evaluated conditions, there is the formation of a jet and the formation of fibers with good spinnability. However, it is also observed that increasing the concentration of polysaccharides in the mixture decreases the amount of fibers formed except for pectin LM, where a significant variation in the diameter of the fibers formed is not observed. When the amount of PEO added is reduced to 0.3%, the diameter of fibers with polysaccharide/zein in the ratio of 90:10 reduces compared to zein/PEO fibers for alginate and pectin LM. Meanwhile, for carrageenan and pectin USPB, the fiber diameter increases. The results revealed that, although electrospinning of polysaccharides is challenging, the mixing of polysaccharide/zein/PEO is an alternative for preparing electrospun fibers to form a fibrillar structure for meat analogs.

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Interfacial and emulsifying properties of olive and sunflower protein hydrolysates 227

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ABSTRACT

There is an increasing global demand in using sustainable plant-based emulsifiers, which could replace animal derived ingredients. Particularly interesting is the production of plant-based emulsifiers from side-streams of food industry, leading to the up-grading of food by-products. Olive and sunflower oil industries generate 350 million tons of by-products (e.g., olive seed and sunflower press-cake), which present an average protein content of 20-25 wt.% in a dry basis. Nevertheless, plant proteins are less soluble and surface active compared to animal proteins, which results in lower emulsifying activity. Notably, enzymatic hydrolysis of plant proteins is an efficient approach to release embedded peptides in the parent plant proteins, leading to hydrolysates with improved solubility and amphiphilicity.

Therefore, this study aimed at investigating the production of olive and sunflower protein hydrolysates exhibiting emulsifying activity by enzymatic hydrolysis. First, the influence of the enzymatic treatment (e.g. Alcalase or Trypsin, degree of hydrolysis of 5%) on the molecular weight distribution of the hydrolysates was investigated. Secondly, the interfacial adsorption and dilatational rheology of the hydrolysates was studied at pH 4 and 7. Synchrotron Radiation Circular Dichroism (SRCD) was used to determine the conformation at the oil/water interface of the emulsifying peptides present in the hydrolysates. Finally, the physical stability of 5% oil-in-water emulsions stabilized with the hydrolysates (2 wt.% protein) at pH 4 or 7 was investigated by evaluating the zeta potential and changes in droplet size distribution and creaming for 7 days storage at 25 °C.

The results indicated that all the hydrolysates showed superior emulsifying activity at pH 7 than pH 4, independently of the enzymatic treatment. Interestingly, sunflower protein hydrolysates, adopting a more marked β-sheet conformation, showed higher interfacial adsorption and led to more elastic interfaces, which resulted in emulsions with higher physical stability when compared to olive protein hydrolysates.

Acknowledgements: This project has received funding from: 1) the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004806 (TNA MOSBRI-2022-98), and 2) Leonardo Grants for Researchers and Cultural Creators 2023 by BBVA Foundation.

Emulsifying activity of plant-protein hydrolysates obtained from by-products of the brewery, whiskey and winery industries: stabilization of echium oil-in-water emulsions 229

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ABSTRACT

Customers' demand for sustainable and healthy food is driving the development of natural, sustainable, and bioactive food ingredients. Echium oil, containing 28% of α-linolenic (C18:3n-3) and 12.5% of stearidonic (C18:4n-3) acids, is a sustainable alternative to fish oil which contributes to meeting the global demand for omega-3 fatty acids. Echium oil-in-water emulsions, which require the use of emulsifiers for their stabilization, are commonly used delivery systems for omega-3 food fortification. In this regard, plant proteins, including those present in food industry side-streams, are widely investigated to produce sustainable and functional ingredients. For instance, the brewery and whiskey industries generate large quantities of spent grains as by-products, which present a high protein content (15-32 %). In addition, the winery industry generates a protein-rich side-stream containing the grape seeds, which can be processed into flour with a protein content ranging from 10 to 15% protein. Thus, these protein-rich by-products from the beverage industry are interesting sources for the development of plant protein-based emulsifiers.

In the light of the above, this study aimed to investigate the emulsifying activity of plant protein hydrolysates obtained by enzymatic hydrolysis of 1) barley spent grains generated by both the brewery and whiskey industries, and 2) grape seed flour. Firstly, the hydrolysates were produced by using Alcalase or trypsin to reach 5% of degree of hydrolysis. Secondly, the hydrolysates were characterized in terms of protein content, amino acid composition and molecular weight distribution. The adsorption of the hydrolysates at the oil/water interface and the viscoelasticity of the hydrolysate interfacial layers were investigated by drop tensiometry at pH 7. Finally, the physical stability of 5% echium oil-in-water emulsions stabilized with the hydrolysates (2 wt.% protein, pH 7) was studied by measuring changes in droplet size distribution, zeta-potential and creaming for seven days of storage at 25 °C.

Acknowledgements: This research has received funding from: 1) Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brazil (CAPES) - Finance Code 001, and 2) Leonardo Grants for Researchers and Cultural Creators 2023 by BBVA Foundation.

Spray dried Buriti oleosomes: effect of different wall materials 232

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ABSTRACT

Buriti (*Mauritia flexuosa* L.f.) has in its composition lipids structured as oil bodies (OB), subcellular organelles found as naturally stable oil droplets. These droplets can be used in food, cosmetic and pharmaceutical industries as a natural and healthy ingredient/additive. Methods such as spray drying are widely used to produce microparticles, and compounds delivery systems with more resistance to degradation. This work aims to produce buriti OB microparticles coated with maltodextrin (M) and two types of Arabic gums (G and GF) through the spray drying method. Buriti OB were extracted by a non-polluting aqueous extraction method. This extract was coated with the wall materials in an emulsion (20% total solids and 20% oil load) and dried on a spray dryer (T_{Inlet}=180±5ºC, T_{Out}=100±5ºC). The powders were analyzed as for water activity, moisture content, apparent density, total carotenoids, and color. The M formulation showed good results with low moisture content and water activity (2.65±0.25 and 0.29±0.08) and better properties compared to G and GF due to maltodextrin solubility and wall forming capacity. Nevertheless, GF also showed promising results for the production of powders with good physicochemical stability. All formulations presented similar apparent density. The highest carotenoid content was found in M, showing that maltodextrin can improve the carotenoid retention in buriti OB microparticles. In relation to the color parameters, the b* parameter suggests that the carotenoids (yellow) are well present in the microparticles and few anthocyanins can be found due to the low a* values (1.98±0.17 - 2.41±0.27). All powders have high L* values (83.66±0.88 - 85.24±1.03) because of the dry agents with light coloration. This study showed that oil bodies can be used as dry agent with coating materials to produce microparticles with interesting compounds to be used in food, cosmetics and pharmaceutical formulations.

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Protein-glutaminase enhances physical stability of plant-based milk substitutes against thermal and aqueous environmental stresses 234

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ABSTRACT

The plant-based milk substitutes are an aqueous dispersion system containing proteins and oil droplets, while they often behave differently from caw milk against thermal and aqueous environmental stresses; for example, almond milk severely forms flocculates/aggregates when blended with hot coffee. Protein-glutaminase (PG) is an enzyme that catalyzes deamidation of glutamine residues in proteins to modify the isoelectric point and conformation, possibly leading to improved physical-chemical properties of plant-based milk substitutes. In this study, the authors investigated effects of PG on physical stability of almond milk in a coffee beverage system.

Raw almond seeds were homogenized with deionized water by a mixer. The homogenate was filtrated to obtain an aqueous extract (almond milk, AM). The AM was subjected to PG treatments (approx. 1 U/g AM protein) for up to 24 h at 50°C, followed by inactivation (85°C, 30 s) to obtain PG-treated AMs (PG-AMs). The deamidation degree was estimated by the ammonia determination. The AM and PG-AMs were blended with coffee (95°C, pH 5.0) at a weight ratio of 1:9. The AM, PG-AMs, and respective coffee mixtures were characterized by particle size and zeta-potential measurements, SDS-PAGE, and visual/microscopic observations.

The deamidation reached to a plateau within 24 h. The SDS-PAGE suggested that amandin, a major almond protein, was deamidated by PG. The particle size distributions of the AM and PG-AMs were not remarkably different, ranging approximately from 1 to 10 µm. The blending test with coffee indicated that the aggregation/flocculation was gradually suppressed along with the progress of the deamidation, resulting in homogeneous mixtures without visible aggregates/flocculates when the PG-AM deamidated for 24 h was used. The PG-AM deamidated for 24 h did not microscopically aggregate/flocculate according to particle size analysis and microscopic observation. The PG-induced changes could be attributed to modified electrostatic and hydrophobic interactions between proteins and oil droplets.

Relating the colloidal state of oat proteins to their food foam stabilizing potential 236

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ABSTRACT

Shifting from animal to plant protein-based foods will be pivotal in transitioning towards a more sustainable global food system. Cereals are the main source of protein in the human diet. Among cereals, oats stand out because of their high level of potentially aqueous-phase-extractable globulins, which may deliver functionality in liquid and semi-solid foods such as dairy alternatives. An important aspect of the oat processing chain is that oat kernels are heat-treated to prolong their shelf-life. Such heat treatment however likely causes extensive protein aggregation, leading to ingredients with poor protein extractability and, hence, limited protein functionality. Recent work from our group revealed that native oat proteins (i.e. isolated from non-heat-treated oats) self-assemble into various colloidal states depending on the environmental conditions (NaCl concentration, pH) [1]. The focus of the present study was to establish relationships between such alterations in the colloidal state of oat proteins and their functional (in this case foaming) properties (**Figure 1**). The colloidal state of oat protein isolate dispersions was assessed with a combination of chromatography, turbidimetry, confocal microscopy and light-scattering based techniques. Foaming tests were performed with a standardized stirring test, while mechanistic insights into the foaming behavior of oat proteins were obtained with (oscillatory) rising bubble tensiometry, interfacial shear rheology and an interferometry based thin film balance equipped with a bikewheel-shaped microchip.

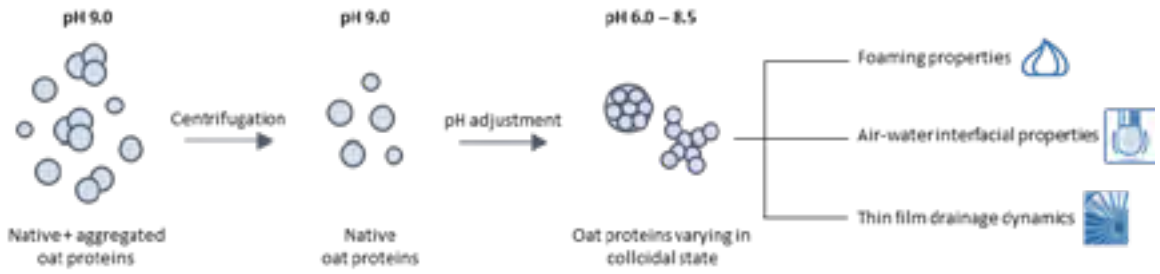

Figure 1. *Schematic representation of the experimental approach.*

References: [1] Wouters, A.G.B. and Nicolai, T. 2024. Self-assembly of oat proteins into various colloidal states as function of the NaCl concentration and pH. Accepted for publication in Food Hydrocolloids.

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Functional, pasting, and thermal properties of starch isolates from three rice variants 240

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ABSTRACT

Rice is an important staple consumed globally and contains starch as one of its major components. Differences in starch properties can affect rice quality and influence their cooking behaviour and application of the starch isolate in the industry. In this study, starch isolated from three rice variants (Australian, Italian, and Vietnamese) was evaluated for functional, pasting, and thermal properties using established methods. Amylose content, gelatinization properties using Differential Scanning Calorimeter (DSC), pasting properties using Rapid Visco Analyser (RVA), water absorption capacity (WAC), oil absorption capacity (OAC) and swelling power of extracted starch were determined. The rice starches showed variable amylose content (approx. 17-21%), which may be due to the source of the grain as well as their inherent genetic differences. Australian starch showed the highest storage modulus (G'), loss modulus (G"), setback viscosity, final viscosity and pasting temperature, which may be associated with its high amylose content. Higher G' has been attributed to gels with high amylose content in rice starch, indicating a well-cross-linked network structure. Australian starch showed the highest setback viscosity, final viscosity and pasting temperature, which may be associated with its high amylose content. Furthermore, the Australian rice starch had the lowest enthalpy of gelatinisation (12.6 J/g) compared with Vietnamese rice starch (14.3) and Italian rice starch (13.8 J/g). Amylose content of these starches showed significant correlations with the pasting properties of the extracted starch as seen in the correlation data for peak viscosity ($r = -0.73$, $p < 0.05$), trough viscosity ($r = -0.77$, $p < 0.05$), breakdown viscosity ($r = -0.71$, $p < 0.05$) and setback viscosity ($r = 0.65$, $p < 0.05$). The data obtained in this study suggest that these starches would have varied application in the food industry, for example, while Australian rice starch can be used as a thickener, Vietnamese rice can be an excellent starting material in sushi rice production.

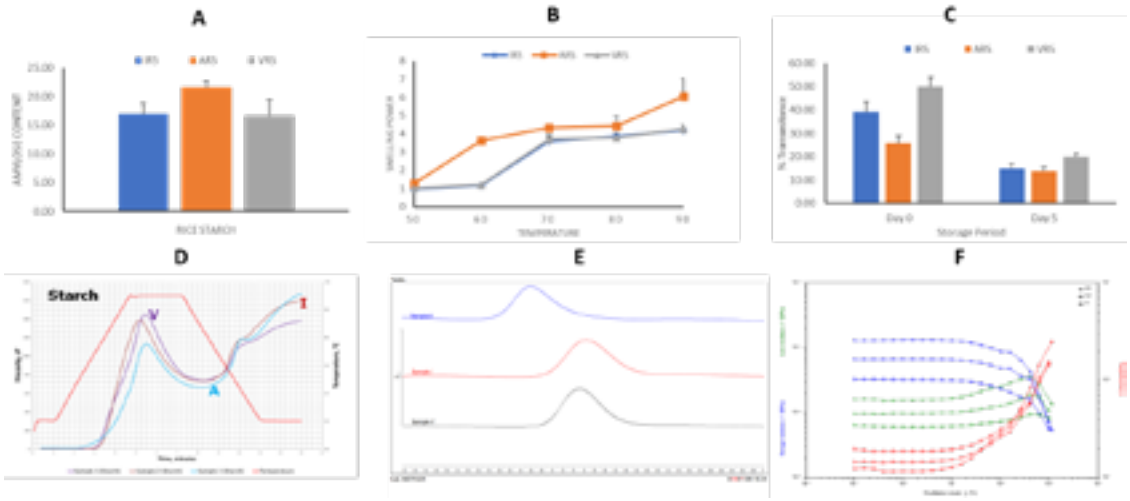

Figure 1. different characteristics of the three rice varieties: (A) amylose content, (B) swelling power, (C) paste clarity, (D) pasting properties, (E) DSC thermogram and (F) viscoelastic behaviour.

Acknowledgements: Authors would like to thank Ichiban UK for providing the rice samples and other resources to get this research implemented.

Composition and emulsifying properties of pea and faba bean protein ingredients as influenced by the processing route: Current state of the art 246

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ABSTRACT

Legume proteins are a promising source in the current protein transition. Growing legumes is environmentally friendly, with their low carbon footprint, high water efficiency, and nitrogen fixation ability. Legumes can be processed into different protein enriched ingredients. A protein concentrate (50-70 wt.% protein) is commonly obtained through dry fractionation, whilst a protein isolate (>70 wt.% protein) requires wet fractionation. This poster reviews the singularities of the two processes and resulting products. Several types of wet fractionation exist, such as alkaline or acid extraction followed by isoelectric precipitation or ultrafiltration and salt extraction. Wet fractionation is less sustainable than dry processing, but produces an ingredient with a higher protein content. Protein ingredients from pea have already been widely studied, whereas other promising sources such as faba bean are emerging more recently. It has notably been shown that the processing itinerary and conditions applied affect the composition and functional properties of pea and faba bean protein ingredients. Often, differences in functional properties are ascribed to the state of the protein molecules. For instance, dry fractionated concentrates have been found to retain a native protein structure, whereas harsher conditions applied during wet fractionation, isoelectric precipitation in particular, induce protein denaturation. Therefore, protein ingredients obtained through isoelectric precipitation have been found to have reduced solubility and emulsifying properties compared to those of dry fractionated or ultra-filtrated ingredients. Yet, current research lacks a comprehensive characterization of the protein ingredients, especially regarding non-protein components and the associated effects on ingredient functionality. Lipids present in the seeds, in particular, can accumulate during the protein fractionation process and modulate the functional properties of the ingredient. In addition, anti-nutritional compounds can be preferentially removed or enriched depending on the applied process. Further research is required to fully understand the complex relationship between protein processing, ingredient composition and ingredient functionality.

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Thermal properties and molecular features of enriched maize flour with grape pomace used in extrusion process 249

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ABSTRACT

The properties of raw materials used in extrusion processing, highly dependent on their chemical composition, impact the extruded product quality. Grape pomace has a wider range of chemical composition profiles and features, depending on the grape variety, wine-making process, etc. which could pose a challenge in extrusion when it is mixed with maize flour. It is very critical to determine the thermal properties and molecular features of enriched maize flour with grape pomace used in the extrusion process to evaluate their extrudability and set up the extrusion process parameters or conditions to accommodate their variations. The aim of this study was to assess the thermal properties and molecular features of the system formed by maize flour and whole grape pomace (10-40%) used in the extrusion process. The whole grape pomace came from two varieties, white and red, and it was preserved by using oven drying and lyophilization methods. Thermal properties, in terms of gelatinization onset temperature (To), peak temperature (Tp), final temperature (Tf), and the enthalpy (DH) of the endotherm were determined by means of differential scanning calorimetry (DSC) to evaluate the extent of starch gelatinization in the maize flour samples enriched with grape pomace. Additionally, the bioactive compounds in the samples formulated were evaluated by means of Fourier Transform Infrared Spectroscopy - attenuated total reflection technique (FTIR-ATR). Different values among samples for the thermal properties, To, Tp, Tf, and DH, for mixtures with white and red grape pomace were observed. Also, the drying methods applied to dehydrate grape pomace and the addition level, impacted gelatinization temperature. The FTIR spectra revealed differences only regarding peak absorbance values depending on the grape variety and drying method. Due to the fact that most extrusion expansion process occurs at moisture levels below 20% on a wet basis, the knowledge of these features helps to understand the thermal properties of the mixtures formulated under similar moisture levels.

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Effect of partial substituting maize flour with seedless grape pomace from white and red variety on the degree of starch gelatinization and molecular characteristics 254

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ABSTRACT

Maize flour, usually used to make extruded products, contains a high amount of starch. Over the years, an increasing demand for snacks improved in fiber was remarked among consumer preferences. The use of fruit by-products such as seedless grape pomace, can generate products that consumers may prefer. The partial substitution of maize flour with seedless grape pomace has been associated with various structural effects in food matrixes. Therefore, a thorough investigation is needed to evaluate the thermal and structural implications of seedless grape pomace addition in maize flour used to make extrudates. The maize flour was substituted with 10-40% seedless grape pomace from white and red grape varieties, and dehydrated by using an oven or lyophilization. The mixtures were analyzed in terms of degree of starch gelatinization and molecular characteristics by using a differential scanning calorimeter (DSC), and a FT-IR infrared spectrophotometer, respectively. The thermal characteristics measured, namely gelatinization onset temperature (To), peak temperature (Tp), final temperature (Tf), and the enthalpy (DH) of the endotherm showed an increase or decrease trend, depending on the amount of seedless grape pomace from mixture, grape variety, dehydration methods, and substitution level. The ATR-FTIR spectra revealed various peaks corresponding to functional groups and modes of vibration of the individual components. The physical and chemical properties of seedless grape pomace-maize flour mixtures formulated impacted the spectral features acquired, but only in terms of peaks intensities.

Acknowledgments. This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS - UEFISCDI, project number PN-III-P4-PCE-2021-0718, within PNCDI III.

Assessing changes in maize-based mixtures formulated with whole and seedless white grape pomace by means of DSC and FTIR analysis 253

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ABSTRACT

Grape pomace is a valuable source of nutrients and bioactive compounds which are essential requirements in the human diet, and we must take it into account when developing novel nutritionally improved products. This study focuses on assessing changes in maize-based mixtures formulated with 0, 10, 20, 30, and 40% whole grape pomace and seedless grape pomace, respectively, from white grape variety, pomace which was dehydrated by applying two methods, convective drying oven and lyophilization, which impact its properties. These formulations will be used as raw materials in the extrusion process in order to obtain extrudates with enhanced nutritional profile. Additionally, the properties of mixtures and their fractions, such as starch, fiber, and protein vary based on their sources resulting in different behaviors during extrusion processing, dictating differences in the extrusion setup and process parameters. Thus, the changes in whole white grape pomace-maize flour mixtures and seedless white grape pomace-maize flour mixtures need to be understood because this could help narrow down the extrusion conditions and ultimately determine the extruded product quality. In this context, the thermal properties were analyzed by differential scanning calorimetry using a DSC 25 calorimeter, and the molecular characteristics were evaluated by means of Fourier Transform Infrared Spectroscopy (FTIR). Thermal properties highlight that the gelatinization onset temperature (To), peak temperature (Tp), final temperature (Tf), and the enthalpy (DH) of the endotherm were different from each other for mixtures with whole and seedless grape pomace oven drying and those with lyophilizate whole and seedless grape pomace. Compared whit the maize sample, overall, an increase in Tp and a decrease in DH was observed with the increase amount of whole or seedless grape pomace in mixtures. There was no considerable difference in molecular characteristics of the mixtures as a function of the amount of grape pomace present in the formulation, only the peaks intensities presenting some changes.

Acknowledgments. This work was supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS - UEFISCDI, project number PN-III-P4-PCE-2021-0718, within PNCDI III.

Effect of protein extraction and extrusion on the functional properties of legume protein 254

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ABSTRACT

The demand for plant-based protein is increasing tremendously on a global basis, since it represents a sustainable, inexpensive and healthier option compared to animal-based protein. Legumes are seen as excellent sources of plant-based proteins due to their high protein content. This study aims to evaluate the functional properties of legume protein concentrates and in particular the effects of extrusion on these properties. The protein content of a laboratory-prepared pea bean concentrate (PB) was highest (77.45 wt%) followed by laboratory-prepared mung bean concentrate (MB), extruded commercial pea bean (EPPI), commercial pea bean "isolate" (PPI), extruded commercial pea bean isolate + shiitake fibre (EPPIS) and laboratory-prepared wing bean concentrate (WB), that contained 76.19, 74.38, 73.75, 72.52 and 61.01 wt% protein, respectively. The particle size of the non-extruded and extruded proteins ranged from 166 to 459 nm. All proteins exhibited good functional properties but did vary to some extent as a function of the legume type and extrusion process. Thus, water adsorption capacity (WAC) was highest for extruded proteins (EPPI and EPPIS) and lowest for the MB, PB and WB protein concentrates. Foaming capacity was generally lower for the concentrates, but they had higher foam stability than the extrudates. No significant difference was observed in emulsifying capacity and emulsion stability between the concentrates and extrudates. However, the protein concentrates had significantly better gelling properties compared to the extruded proteins, which showed no gelation at all. The reasons for some of these large differences in functional properties are discussed in terms of the structural effects of the extrusion, which is of great significance to the commercial utilization of such materials.

Acknowledgements: Authors acknowledge the Ministry of Higher Education (MOHE) for funding under the Fundamental Research Grant Scheme (FRGS) (FRGS/1/2021/WAB04/UITM/02/1)

Modification of Vicia villosa protein isolate using Cold atmospheric plasma: Impact on the functional and interfacial properties 257

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ABSTRACT

In recent decades, one of the current hot topics in food science is to replace animal-derived proteins with plant ones. Legum proteins are the richest source of proteins that are widely used in food colloidal systems. Despite their advantages, they also have some weaknesses, such as low interfacial properties and solubility. So, In the past few years, intensive research has been conducted on the modification of their technofunctional and interfacial properties. Cold plasma processing as a nonthermal, green, and low-cost technique, has recently gained much attention for the modification of proteins. Highly reactive species produced during the plasma processing can react with the side chains of specific amino acids, alter the secondary and tertiary structure and modify the technological properties of proteins.

The interaction between atmospheric cold plasma and Vicia villosa protein isolate (VVPI) powder was investigated as a function of treatment time (for 3, 6, 9, 12 min at 26 kV). Then the effects on pH, particle size, surface hydrophobicity, sulfhydryl groups and functionality were studied. The results showed Following ACP treatments for 9 min, mild oxidation occurred in the proteins. This was evident from an increase in surface hydrophobicity, besides the reduction of free SH groups; The protein structure modifications revealed a certain degree of unfolding, as confirmed by dynamic light scattering, which improve solubility and emulsifying capacity. However, the prolong plasma treatment negatively affected the solubility.

Molecular mobility of Xanthan gum hydrocolloid and hydration effects 275

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ABSTRACT

Xanthan gum (XG) has attracted much attention in the scientific community due to its non-toxic and eco-friendly characteristics. It is a microbial polysaccharide of *Xanthomonas* campestris, the structural unit consisting of a pentasaccharide, comprising glucose, mannose, and glucuronic acid. Because of its biocompatibility, hydrogen bonding properties, good electrolytic compatibility, and low cost, it is used in a wide range of applications including the food industry and biomedicine. Given the fact that water is an essential factor for all biological processes as it affects remarkably the chemical reactions of biopolymers, it is highly significant to shed light on the way that hydration affects biopolymers. In this study, we focus on the molecular mobility of XG by employing dielectric relaxation spectroscopy in samples with different water contents ($0 \leq h_w \leq 0.70$ on the wet basis). The complex dielectric function was determined isothermally as a function of frequency, *f,* in the range from 10^{-1} to 10^{6} Hz at temperatures from -150°C to 30°C in steps of 10 degrees, during heating. We have also performed isochronal measurements during cooling in order to monitor any crystallization event that may occur. Our results indicate that ice formation occurred during cooling only for the samples with the highest water contents (h_w=0.36 and 0.70). The results of the fitting procedure, show the existence of a relaxation process that follows an Arrhenius law. It has its origin in the polar-hydrophilic groups of the polysaccharide and is strongly plasticized by the absorbed water. Interestingly, for the sample with h_w=0.27, where no solid water phase exists, an additional process that shows a VTF temperature dependence has been recorded which, as we show, is related to a conductivity current relaxation mechanism. For higher water contents two relaxation processes that are activated in the formed ice phase are recorded already at the lowest temperature of the measurements.

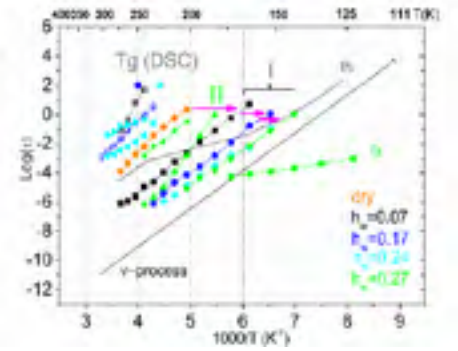

Figure 1. Arrhenius plots of mean relaxation times of processes recorded on the samples at rather low hydration levels (h_w=0-0.27)

Hydration effects on thermal transitions of xanthan gum hydrocolloid 276

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ABSTRACT

Xanthan gum (XG) is an extracellular hydrocolloid of high molar mass that is secreted by the bacterium *Xanthomonas* campestris. It is widely used in a wide range of applications in the food industry as well as in biomedicine. As a natural biopolymer offers some very important advantages such as biodegradability, biocompatibility, and nontoxicity. On the other hand, it is well known that water plays a vital role in all biological processes and is requisite to life and human activity because it affects significantly the catalytic chemical reactions of biopolymers while it acts as a medium that determines the dynamics and structure of biopolymers. Therefore, it is of great importance the study of hydration effects in biopolymers.

In this context, the aim of this work is to study the thermal transitions of XG in a variety of water contents ($0 \leq h_w \leq 0.70$ on the wet basis) by employing differential scanning calorimetry. The temperature range of measurements was from room temperature, 25°C to -150°C (cooling) and vice versa (during heating). The investigation reveals that water crystallization events occur only for the samples with the highest hydration levels (h_w=0.36 and h_w=0.70). This means that, depending on the water content, the absorbed water is organized as bound water/ interfacial water and bulk-like water that can form a separate ice phase at subzero temperatures. With respect to the glass transition, during standard scans, it was recorded for all the samples except dry and the one with the lowest water content (h_w=0.07). Especially for these two aforementioned samples, and to ensure whether glass transition exists or not, apart from standard DSC runs temperature modulation DSC experiments (TMDSC) were also performed. The results revealed that the temperature of glass transition, T_g, decreases systematically with increasing water content demonstrating that water acts as a strong plasticizer. The plasticization ceases for water contents where ice is formed during cooling.

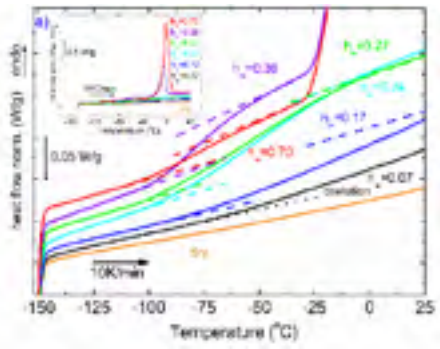

Figure 1. DSC heating curves focusing on the T_g region are demonstrated. Water seems to act as a strong plasticizer, resulting in a decrease in T_g with increasing water content

Potential of ora-pro-nobis (Pereskia aculeata Miller) fruit for protein extraction 277

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ABSTRACT

Pereskia aculeata Miller is a Brazilian native cactus common throughout the national territory, popularly known as ora-pro-nobis (OPN). Unlike other cacti, OPN presents developed leaves with high nutritional value, with considerable concentrations of proteins (14.3-29.0%, in mass), vitamins, total dietary fiber, carbohydrates (29.5-32.3% in mass), and minerals (calcium, magnesium, manganese, and zinc). During its adult phase, OPN produces edible fruits (Figure 1), which are not currently consumed. The evolution of the OPN fruit, from its formation to complete ripening, is described in detail, including changes in color, pulp texture, and seeds. A study conducted by [1] extracted mucilage from the green fruit of OPN, showing a protein concentration (19.89±0.19 %) higher than that found in mucilage extracted from the leaves (8.89±0.17 %) [2]. However, there is a gap in research regarding the characterization of the OPN fruit at different stages of ripeness. Thus, this work aimed to quantify the protein content of the whole fruit and its structural parts (epicarp, mesocarp, and endocarp) in the three fruit ripening stages green (GF), intermediate (IF), and ripe (RF), focusing on evaluating the potential of this fruit as a source of this macronutrient. In the whole form, the samples presented the following protein percentages (%): GF (13.86±0.12), IF (15.33±0.09) and RF (16.8±1.29). The yield (%)/protein (%) of each part of the fruit were: epicarp GF (15.80±0.33/9.95±0.80), IF (15.70±0.32/9.54±0.27) and RF (17.98±0.29/10.56±0.56); mesocarp GF (77.75±0.31/12.52±0.29), IF (76.95±0.37/10.53±0.52) and GR (77.81±0.32/15.73±0.26); endocarp GF (6.58±0.29/22.40±0.45), IF (7.35±0.22/27.77±0.76) and RF (4.2±0.21/24.96±1.42). The SDS-PAGE electrophoresis analysis of the whole fruit extracts (Figure 2) showed a rich protein profile, with 5 bands identified, with a wide range of molecular mass, ranging from 15.0 to 37.0 kDa. The results obtained in this study encourage further investigation of the nutritional and techno-functional properties of proteins derived from the OPN fruits.

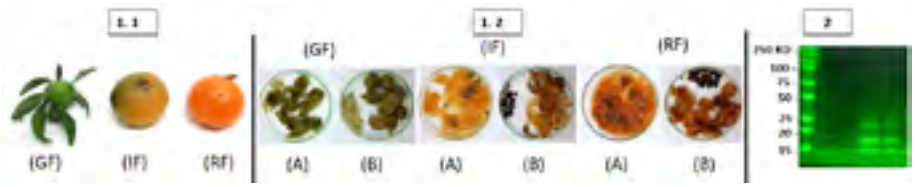

Figure 1.1. Degree of ripeness of OPN fruits: Green fruit (GF), Intermediate fruit (IF), Ripe fruit (FR); 1. 2. Endocarp (A), Epicarp and Mesocarp (B). Figure 2. Whole fruti SDS-PAGE electrophoresis.

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Acknowledgements: Pró-Reitoria de Inclusão e Pertencimento (PRIP) - University of São Paulo (USP) for funding (fellowship of Sérgio H. Silva) and support.

Use of carob (*Ceratonia siliqua*) ingredients to increase the efficiency of alginate bead encapsulation of lactic acid bacteria 278

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ABSTRACT

Lactic acid bacteria (LAB) are a diverse group of microorganisms present in plant products, fermented foods and various other ecosystems. LAB are generally regarded as probiotic microorganisms because through their metabolic activity they produce a wide range of bioactive compounds with health-promoting properties. However, in order to maintain their probiotic character, LAB should retain their viability throughout food processing and other stress factors. Encapsulation of the bacterial cells in natural hydrogels of algal, plant, animal or bacterial origin could act as a barrier between the core material and the external environment improving the survival of beneficial microorganisms added to different food matrices. Moreover, encapsulation facilitates the delivery of biologically active compounds in food systems. Alginate is a hetero-polysaccharide hydrocolloid mainly found in brown algae, widely used for probiotic encapsulation due to its simplicity, biocompatibility, and low cost. Carob (*Ceratonia siliqua*) is a generally underutilized tree mostly found in the Mediterranean Basin, although its fruit is very nutritious and rich in many bioactive substances such as polyphenols and could be considered a functional food. In this study, the encapsulation of various lactic acid bacteria into calcium alginate beads enriched with carob ingredients such as carob gum (also a hydrocolloid), carob flour and carob syrup was investigated in terms of the encapsulation efficiency, physical properties of beads and viability of probiotics through the *in vitro* passage of the gastrointestinal system. Results have shown that the encapsulation efficiency was >90% in all tested encapsulated bacteria, however the carob ingredients have acted as a protection barrier for the lactic acid bacteria through the *in vitro* gastrointestinal simulation studies, maintaining their viability in higher levels compared to the control samples (only alginate beads). Further research is needed to develop efficient carrier systems for probiotics by using low cost local plant materials.

Effects of guar gum on the surface and conformational characteristics of quinoa protein isolate in aqueous dispersions 283

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ABSTRACT

Quinoa protein possesses a superior nutritional profile with great potential in food applications. The conformational and structural properties of quinoa proteins can be affected by extrinsic factors such as the presence of other components (e.g., stabilizers or thickeners). Thickeners play a major role in the formulation of beverages with modified texture. Guar gum (GG) is a natural polysaccharide with a wide range of commercial and industrial applications in water formulations. This study aimed to understand the role of GG in conformational properties and secondary structural changes of quinoa protein isolate (QPI) in a model aqueous system. QPI dispersions (3%) and blends with 0.25 % (w/v) of GG were characterized in terms of charge, size, solubility, hydrophobicity, and conformational changes, focusing on the secondary structure analyzed by FTIR and Raman spectroscopy. The results showed that the surface charge of QPI was significantly modified ($p<0.05$) in the presence of GG, and the isoelectric point of QPI decreased from 4.7 to 3.1 with GG. The intrinsic fluorescence intensity decreased in the order of QPI>QPI-GG, indicating that hydrophobic amino acids, such as tryptophan, were oriented toward the interior of proteins, along with the formation of protein- polysaccharide complexes. The solubility of the proteins decreased from 38% to 13% in the presence of GG. FT-IR and Raman spectroscopy analyses demonstrated that conformational rearrangements of QPI occurred due to interactions with GG. Furthermore, observations suggest that the use of GG-like thickeners in beverages based on plant proteins affects their secondary structure, associated with an increase in α-helix, pseudo β- sheet, and an increased random coil structural state. This could also improve the digestibility of quinoa proteins, although further digestion studies are necessary to validate this hypothesis. This research will enrich the application of QPI in plant-based beverages with modified textures.

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Aqueous extraction of dietary fibers from wheat shorts under subcritical conditions and incorporation into cocoa flavored milk for κ-carrageenan replacement 296

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ABSTRACT

Shorts is a by-product of the wheat milling industry, rich in dietary fiber (DF), such as arabinoxylans (AX) and β-glucans (BG); therefore, valorization of this food processing waste could be achieved by their extraction. These ingredients have been studied in food systems, as they can act as stabilizers, emulsifiers, fat replacers, viscosifiers and gelling agents. The incorporation of AX and BG in food products, taking advantage of their functionalities, is further promoted by the increasing consumer demand for 'clean label' products. The objective of this study was the application of subcritical aqueous extraction, as an ecofriendly method, using only water under high temperature and pressure conditions, to obtain the DF fractions of shorts and to incorporate them into high protein cocoa flavored milk (HPFM) beverages, instead of the usual stabilizer, e.g., carrageenan. For extraction of DF, destarched and deproteinized shorts were subjected to ultrasound treatment (20 kHz, 117 Watt) for 0, 15 and 30 min, followed by subcritical water extraction at 120, 140 and 160 °C at 70 bar for 30 min. All obtained isolates contained ~10% proteins and ~80% DF with the extraction yield being between 8.5-11.0% w/w. HPLC-SEC-RI chromatography revealed that the ultrasound treatment did not affect the molecular weight of the extracted DF, which was between 175 to 195 kDa. The DF extracts were incorporated into HPFM at 1.0, 2.5 and 3.0% w/w levels, resulting in enhancement of product viscosity in a concentration-dependent manner, with the 2.5% level having similar rheological behavior to a control sample prepared with 0.03 w/w κ-carrageenan. Cocoa powder sedimentation was macroscopically observed only in the case of 1.0% of added DF. Overall, it appeared that DF from wheat shorts can be promising ingredients for carrageenan replacement in 'clean label' milk-based products increasing their nutritional value as well.

Acknowledgements: This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code: T2EDK-00468).

Lactic acid bacteria as building blocks for food structure 317

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ABSTRACT

Gram positive bacteria, such as lactic acid bacteria can be considered as colloidal building blocks adhering to interphases and taking part in formation of food structures depending on the their surface chemistry and surface properties. The surface properties of LAB can be characterized by physical chemical assays [1] and measurement of natural variation of LAB reveals variation ranging from hydrophilic to hydrophobic and neutral to strongly negatively charged surface potential [2]. The surface properties can be further tuned by adsorption of proteins and polymers [1] and chemical grafting of hydrophobic molecules to the peptidoglycan of the bacteria [3]. Bacteria with hydrophobic surface properties can be used as Pickering particle for the stabilization of foams [4], emulsions [3] and double emulsions formed in a single step [5]. Using micro air bobbles as templates staple colloidosomes (hollow particles) can be assembled by initial adsorption of hydrophobic bacteria and subsequent ingress of water [6]. The properties of the colloidosome can further be modified by layer-by-layer adsorption of polymers and other bacterial strains and permeability can be tuned depending on wall thickness and zeta potential. Lactic acid bacteria can fully substitute fat globules in whipping creams, where the foam structure reveals air bobbles covered by bacteria and astructural network of bacteria providing stiffness and preventing drainage of the serum phase [7].

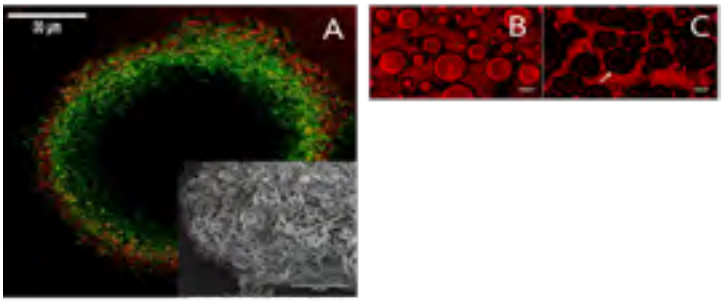

Figure 1. (A) Colloidosome formed by two species of bacteria. Structure of whipping foam based on hydrophobic bacteria (B) and hydrophilic bacteria (C)

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Application of Plant-Based Microgel Reinforced Hydrogels for Fat Replacement 320

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ABSTRACT

Obesity, affecting over a quarter of adults in the UK, increases life-threatening conditions, including diabetes, heart disease, and many cancers. A major challenge within the food industry is therefore formulating healthier products such as replacing calorie-dense fat in food matrices with low-calorific ingredients without sacrificing the mouthfeel experience offered by fat. Using proprietary plant protein-based microgel-reinforced hydrogels [1], this study aimed to assess the oral lubrication and sensory perception of these unique composite hydrogels when incorporated in different food matrices. Ball-on-disc tribology, and discriminative studies with ninety-three participants, including 38 males and 55 females with an average age of 27.08 years were performed. This two-component microgel reinforced hydrogel lubricant composed of proteinaceous microgels and biopolymeric hydrogels was capable of surpassing the lubricity of fat with friction coefficient < 0.01 as measured using tribological tests using both smooth and textured surfaces, latter mimicking the human tongue's wettability, topography, and compliance [2]. Strikingly, the rheological and tribological properties of low fat food matrices such as low-fat yoghurt and salad dressings containing microgel-reinforced hydrogel lubricant closely resembled those of full-fat counterparts. Additionally, in triangle sensory tests, substituting up to 50% of the fat content in the afore-mentioned food matrices with the microgel-reinforced hydrogel lubricant did not yield any significant difference ($p > 0.05$) compared to their full-fat counterparts. This innovative microgel-reinforced hydrogel lubricant showcasing superlubricity, holding immense promise as an ingredient to meet the escalating demand for low-fat sustainable food products while maintaining a desirable sensory experience.

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Improvement of emulsification and interfacial properties of yeast cytoplasmic proteins through enzymatic modification 326

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ABSTRACT

The enzymatic modification of proteins has been shown to have significant impacts on a protein's ability to form stable emulsions and interact at hydrophobic interfaces. Proteins reclaimed from yeast waste streams such as spent brewer's yeast have also been shown to contain valuable protein-based functional ingredients. In this work, proteins derived from the yeast cytoplasm have been oxidatively crosslinked by laccase from *Trametes versicolor* to modulate their emulsification and interfacial properties.

Yeast cytoplasmic proteins were combined with laccase to achieve varying levels of crosslinking over reaction time course, employing ferulic acid as an enhancing phenolic mediator. Emulsification properties of native and modified proteins were assessed via turbidimetric analysis, while interfacial properties were examined using the maximum bubble pressure method and the drop volume method.

The reaction time courses led to enhanced crosslinking that was found to be dependent on the number of enzyme units applied, the reaction length, and the addition of ferulic acid. The extent of crosslinking was correlated with higher proportions of the protein with an increased molecular weight. Modified yeast cytoplasmic protein demonstrated enhanced emulsion stability, especially at pH 4. Yeast proteins modified without ferulic acid showed an increased initial adsorption rate and decreased equilibrium surface tension, whereas those modified with ferulic acid displayed the opposite trend.

Yeast derived proteins were successfully crosslinked using laccase from *T. versicolor* with the addition of a phenolic mediator and extent of crosslinking can be controlled by varying the reaction conditions. The modified proteins show promising improvements in emulsification potential and interfacial activity. The understanding of the relationship between the extent of crosslinking and the functional properties will provide the capability to generate enhanced protein-containing biopolymer matrices.

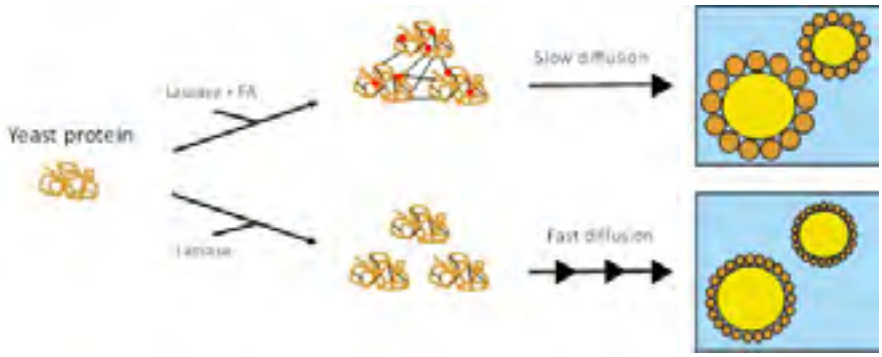

Figure 1. Laccase modified proteins traveling to the oil water interface

Acknowledgements: Support has been provided by the FRQNT, McGill University and Mitacs Globalink

Rheological properties of novel hydrocolloids: the case of Persian gum 337

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ABSTRACT

Persian gum (PG) is an exudate polysaccharide from the trunk and branches of wild almond tree mainly native to Iran and has recently attracted the attention of many researchers due to its unique properties and potential applications it may find in the food sector. This gum is transparent, semi cloudy and odorless and can be found in different shapes such as large granules, sugar crystals and powder with diverse colours. In order to evaluate the rheological properties of the PG two techniques have been used; for the determination of the intrinsic viscosity the viscosity of aqueous solutions of PG (0,01– 0,5 w/v) were measured with Ubbelohde capillary viscometers at 20 °C, while the flow behavior was studied by measuring steady shear viscosity over a range of shear rates 0.01–1000 (1/s) for PG solutions (1-6% w/w). The results of the rheological measurements demonstrated a shear-thinning behavior while the effect of temperature was very apparent for all the concentrations studied. Such information is of great importance for the use of PG as stabilizer or thickener in the food industry.

Mild Aqueous Extraction of Hemp Seed Oleosomes: Tunning Hempseeds Oleosomes Cream properties by adding Hempseeds Protein Concentrate 338

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ABSTRACT

Oleosomes or Oil Bodies (OBs) are micron-sized organelles formed during seed development and maturation in plants to act as an energy reservoir for important processes such as germination. They consist of a hydrophobic triglyceride core, surrounded by a protein-phospholipid membrane with a hydrophilic surface. It has been reported that OBs can be intactly extracted from high-oil plants, and subsequently assembled into food materials with appealing attributes, exploiting the inherent principles of nature's design. Hempseed is a promising crop whose production and consumption align with the SDGs objectives proposed by the UN in terms of sustainability and health. Even though its oil, protein and dietary fiber are highly nutritious, more exhaustive research is needed to enhance the properties of extracted Hempseeds OBs for use as functional ingredients in palatable foods.

A mild-extraction procedure of Hempseeds OBs, which used just water as solvent and where no other reagents where needed, led to an OBs cream of over 76% of hempseeds oil, a solid fraction high in insoluble fiber, and a protein-rich pellet (Protein Concentrate), obtained after centrifugation process, which contained more than 70% d.w. of protein, mainly composed by Edestin, according to the results showed by SDS-PAGE.

Physicochemical characterization of the OBs and Protein-rich fractions was assessed. Besides chemical composition, particle size and ζ-potential of the colloidal systems dispersed in water were analyzed, and their corresponding microstructures were seen under CLSM, thus confirming that some modifications, such as pH adjustments, induced changes in the microstructure of the systems. Changes in the OBs cream stability were analyzed after mixing the suspension with different amounts of the Protein Concentrate, which could tune the properties of the potential food product.

Understanding the interaction between hempseed oleosomes and storage proteins within a food matrix can potentially enhance the utilization of these functional ingredients.

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P4. COLLOIDS IN HUMANS DELIVERY SYSTEMS, BIOAVAILABILITY, DIGESTION AND ORAL PROCESSING

Interactions between hydrocolloids, phenolic acids, and mucins: Towards a molecular-level astringency model 28

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ABSTRACT

In the last decade, proteins and polysaccharides have been considered as diminishers of astringency by their disruption of the aggregation between polyphenols and salivary proteins; however, a lack of understanding exists on the physicochemical basis of such phenomena. In this work, the molecular and colloidal-level interactions between model phenolic acids (e.g. gallic acid), model hydrocolloids (e.g. guar gum) and mucin, the major component of food saliva, were studied in ternary systems at pH values 3 and 7, representative of the pH values of human mouth and stomach during the ingestion of hydrocolloidal polyphenol-containing foods. Spectrophotometric, fluorescence, rheological and light scattering measurements have been used to this aim. The results shed light on the functionality of polysaccharidic – phenolic acid complex systems upon consumption, highlighting the regimes of stability and phase separation as polyphenol-containing foods are inserted into the oral cavity, are mixed with saliva and are swallowed into the stomach. The output can be used as a theoretical base for understanding the phase-separation-based oral sensations like astringency, and the fate of relevant foods in their transit from the oral to the gastric region. In addition, it can help as model to understand the differences in oral perception observed in xerostomic populations.

Acknowledgements: The research work was supported by the Hellenic Foundation for Research and Innovation (HFRI) under the 4th Call for HFRI PhD Fellowships (Fellowship Number: 9261).

Development of highly stable phytosterol oleogel particle-based emulsions with improved bioaccessibility of β-carotene 58

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ABSTRACT

Oral administration is the most preferred route for drug and bioactive delivery, although it raises great challenges due to the involvement of the gastro-intestine system and limited bioavailability. In this research, gelled oil particle-based emulsion was formulated using β-sitosterol and γ-oryzanol (SO) mixtures, as structuring agents, to improve the β-carotene bioaccessibility.

The effect of SO concentration was analyzed under simulated GI conditions and changes in their particle size, zeta potential, and morphology was assessed. Furthermore, these differences were examined with respect to the oleogel particle susceptibility to gastrointestinal digestion and β-carotene bioaccessibility kinetics.GI digestion tests revealed that unstructured oil particles-based emulsions incubation in the stomach phase promotes particle aggregation and consequently leads to particle size increase in comparison to the structured oil particles-based emulsion. In the small intestine phase, the extent of lipid digestion was correlated to the particle size and the oleogel-network mechanical strength. More specifically, higher SO concentration led to stronger network that hindered lipolysis process, on one hand, while on the other hand, higher SO concentration also led to particle size decrease resulting in higher total extent of lipolysis. It was shown that smaller mixed micelles are formed during the lipolysis process when particles were prepared using higher SO concentration, implying on the ability to control micelle size during digestion. Moreover, the β-carotene bioaccessibility kinetics was directly related to the original particle size and density of the lipid phase that was controlled by the SO concentration. Overall, the results suggest that the combination of solid texture and liquid lipid core found in oleogel system offers mechanical protection and micellization ability during digestion. Therefore, the obtained oleogel particles-based emulsion has the potential to be utilized as effective encapsulation systems for hydrophobic molecules with controllable release by manipulating the biophysics of the chosen lipid and structuring agent network.

Black tea increases the threshold of greasiness sensation and enhances emulsification capacity of human saliva 72

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ABSTRACT

As the most popular drink worldwide, tea (*Camellia sinensis*) is often consumed together with meals. One of the benefits of pairing tea with meals is reducing the greasiness sensation of fatty food. The rich content of amphiphilic compounds and nano-size complexes (nanoparticles) in the tea infusion could serve as natural emulsifier to affect oral emulsification and sensation. Saliva, a natural and endogenous emulsifying agent, plays a crucial role in the oral processing of fats, too. This study assessed the combined influences of a Chinese black tea and saliva on the threshold of perceiving greasiness of oily food (rice bolus with a serial concentrations of olive oil) by a sensory penal. Subsequently, the effects of black tea on the oil/saliva emulsion were assessed by determining oil holding capacity, particle size distribution, friction coefficient, apparent viscosity, three-phase contact angle, and morphological profiles of droplets. The results demonstrated that the black tea infusion significantly elevated the subjects' threshold for greasiness sensation. At low oil content (18%), the emulsifying performance of saliva emulsions with or without tea infusion showed no significant difference. While at the higher oil contents (≥40%), saliva-tea emulsions (saliva:tea=1:1, v/v) exhibited superior oil-holding capacity, the lower apparent viscosity and friction coefficients, and the stronger hydrophilicity at the hydrophobic surface, comparing to those of saliva-water (saliva:water=1:1, v/v). The microscopic observation revealed that the presence of black tea reduced the droplet size of emulsion, prevented flocculation and delayed oil/water phase separation. This study provides new insights into tea-drink induced changes in the human perception of greasiness and the *ex vivo* emulsification behaviour of human saliva, which will help to better understand the molecular mechanism underpinning the anti-greasiness and mouth feel of tea drink. Future study will be taken to distinguish the contribution of major compounds and complexes in tea infusion.

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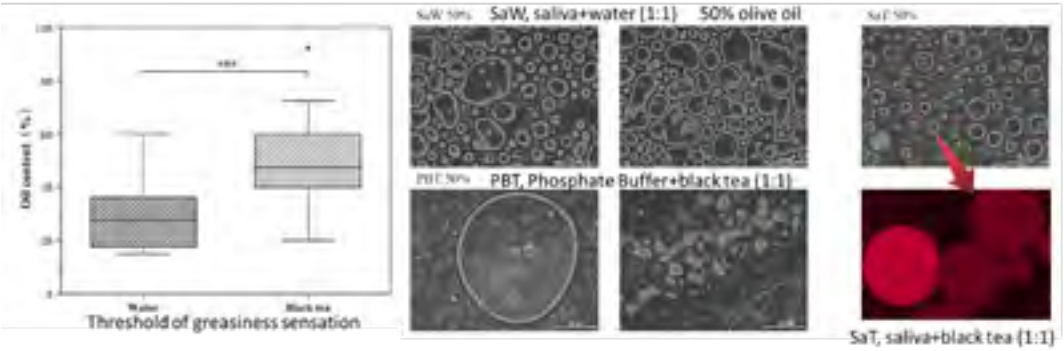

Figure 1. Influences of black tea on threshold of greasiness sensation and morphology of emulsion droplets

Acknowledgements: The research was supported by The 'Pioneer' and 'Leading Goose' R&D Program of Zhejiang (2022C03138). Prof. Jianshe Chen from Zhejiang Gongshang University is acknowledged for his help in methodology development and providing access to the lab facilities.

Mucoadhesion ability of protein and starch from lotus (*Nelumbo nucifera Gaertn.*) seeds, relative to milk casein, gelatine and gum arabic as well-recognized mucoadhesive biopolymers 89

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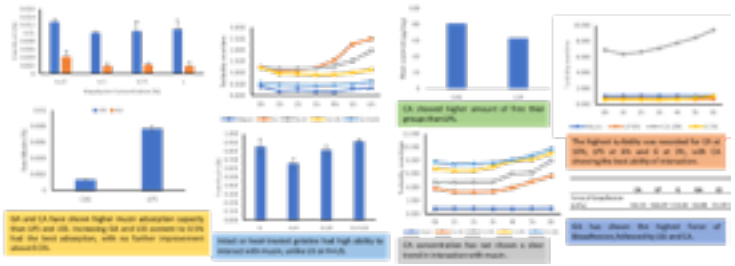
ABSTRACT

The objective of this study was to investigate the mucoadhesive properties of lotus seed starch (LSS) alongside gum Arabic (GA), as well as lotus seed protein (LSP) alongside milk casein and gelatine. The ability of the biopolymers to interact with mucin was studied through mucin adsorption assay, turbidity during 6 h of interaction and viscosity increase (known as the 'force of bioadhesion'). The thiol content of proteins was also determined to understand the origin of mucoadhesion. The interaction was studied at different biopolymer concentrations (0.25-1% for polysaccharides and 2-10% for proteins, except for G which was studied at 1-5%). Samples were also treated with thermal treatment (H, 85^{0}C/30 min), ultrasounds (US, 50% amplitude at 40^{0}C/30 min) or heating followed by ultrasounds (H+US) to study the impact of such treatments on the mucoadhesion ability of proteins. Polysaccharides were only treated by US. The mucin adsorption and interaction with biopolymers have shown a clear trend with a descending order of GA > LSS > CA > G > LSP. GA and CA have shown higher mucin adsorption capacity than LPS and LSS. Increasing LSP concentration showed a decline trend in mucoadhesion, unlike CA which showed an opposite trend, with maximum adhesion at 10% protein content. The increase in G content to 3% showed the maximum adhesion, which was then declined with further increase in concentration to 5%. Increasing GA and LSS content to 0.5% had the best adsorption, with no further improvement above 0.5%. The thiol content assay for proteins supports this result as milk casein had higher thiol content than LSP which evidences higher mucoadhesive interaction in milk casein. Intact or heat-treated gelatine had high ability to interact with mucin, unlike US or H+US, which reduced adhesion. However, higher mucoadhesion has been shown by CA when treated with US only. On the other hand, LSP did not show considerable changes with any of the treatments. The ability of LSS to bind mucin increased with US treatment.



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Formulating cellulose nanocrystal Pickering emulsions and their impact on lipid digestion 102

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ABSTRACT

Understanding the process of lipid digestion and absorption and using effective ways to control it is paramount for the development of food formulation strategies to address the obesity crisis.

To develop and characterise Pickering emulsions stabilised by cellulose nanocrystals (CNCs) or combined with other polysaccharides, including methyl cellulose (MC) and chitosan (CS), to regulate lipid digestion, using simulated in vitro digestion.

CNCs alone, or in combination with MC or CS were used to generate Pickering emulsions. CNCs were characterised by atomic force microscopy (AFM), dynamic light scattering (DLS), and emulsions by laser diffraction and fluorescence microscopy. The pH-stat method was used to measure free fatty acids (FFA) release.

CNCs were rod-like (length = 81.9±0.3 nm) and a negative ζ-potential (-53 mV). All formulations generated stable emulsions, however emulsions utilising CNCs alone demonstrated significant instability in the simulated intestinal environment. The combination of CNC with MC or CS resulted in greater stability and reduced FFA release in vitro.

CNCs can be used to stabilise Pickering emulsions alone. Utilising CNCs, in combination with polysaccharides with different physico-chemical properties, has potential to generate novel food emulsion systems for improved regulation of lipid digestion.

Saliva: A foamy, stretchable hydrocolloid that is always present in our food 225

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ABSTRACT

Saliva is the very last ingredient to be added into the food before digestion. One must consider saliva as an integral component of the bolus in order to understand the structural aspects of digestion and nutrients bioabsorption, and well as the special conditions that are induced upon saliva's deficiency (as in xerostomia/dry mouth). Understanding, thus, saliva as colloidal food is necessary for assessing its effect as part of the digested bolus. To this end, this study examines the physicochemical characteristics of unstimulated whole human saliva in its foamed and non-foamed state, as well as its serum. The study focuses on the shear and extensional rheological properties of the biofluid, as well as on colloidal properties such as the size of the particles that are suspended in fresh saliva, their size distribution and ζ-potential. Saliva foam volume fraction is also assessed as function the shear resulting from the movement of the tongue against the palate, along with interfacial properties such as the contact angles formed by saliva over oral surfaces such as epithelium, enamel, and dental filling materials, and over food materials such as cellulose and lipid matrices. The collected data are considered under the light of phase separations in saliva, including foaming behavior, foam stability/lifespan and precipitations within the oral cavity within the timespan of oral processing. The above provide insights on the kinetics of bolus formation during mastication and on cases of deficient functionality (e.g. in incomplete foaming or low mucin composition) as guidelines for the formulation of salivary substitutes.

In vitro protein digestibility of different soy-based products: Effect of microstructure, physico-chemical properties and protein aggregation 255

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ABSTRACT

This study investigates the effect of protein structure and food microstructure on *in vitro* protein gastrointestinal digestibility of different soy-based products, i.e. soy drink, reconstituted soy drink powder, firm tofu and yuba. The results of chemical cross-linking analysis showed that hydrogen bonds and hydrophobic interactions were the main forces driving protein aggregation in (reconstituted) soy drink powder and firm tofu, whereas disulphide bonds were significantly more important for soy drink and yuba. The β-sheet content of soy drink (36.5%) was lower than yuba (43.3%), but significantly higher than soy drink powder (23.2%) and firm tofu (29.8%). The *in vitro* protein digestibility decreased in the order: firm tofu > reconstituted soy drink powder > yuba > soy drink. Principal component analysis showed that protein gastrointestinal digestibility was positively correlated with the surface SH content and soluble protein content released by SDS + Urea (SB-SA) but negatively correlated with the disulphide bonds and β-sheet content for the four soybean products.

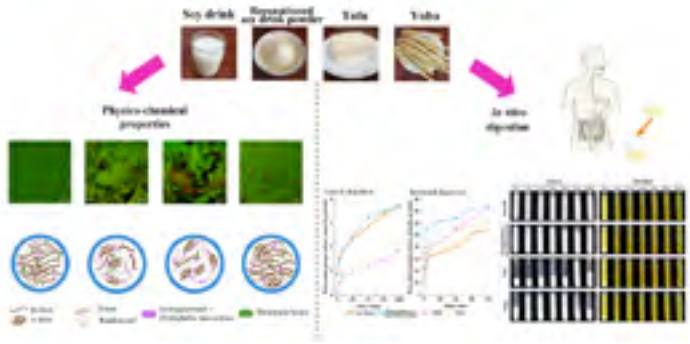

Figure 1. The four soybean products have different protein structure and food microstructure which significant effect the protein *in vitro* gastrointestinal digestibility.

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Adsorption and Consumption of Hydrolysed Pectins by Gut Bacteria 280

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ABSTRACT

Most *dietary fibers* (DFs) are carbohydrate polymers that resist the hydrolytic digestive enzymes released in the human gastrointestinal tract (GIT). DFs, however, are fermented by our *gut microbiota*, a diverse and numerous group of microorganisms present in our large intestine. The gut microbiota and its fermentation products are vital in maintaining our overall health and well-being, from nutrient adsorption to disease prevention [1], [2]. DFs are therefore relevant macromolecules for our society. *Pectin* is an abundant DF in plant products, and it is widely used both in the food industry as a natural thickener, and pharmaceutical sector for its gelling abilities [3], [4].

Much work examining DF and microbiota focuses on health, its genetics, and the correlation between food intake, microbiota composition, and metabolism. The chemical comprehension of the polysaccharides-bacteria interaction is extensive [5], [6]; still, there is little physical understanding of topics such as adhesion between polysaccharides and bacteria or polysaccharide conformation on the bacteria surface. This research aims to shed light on the matter by investigating the interaction of gut bacteria with pectin.

Pectins coming from two different sources have been hydrolyzed, both chemically and enzymatically, and characterized in detail [7]. We employed an *in-vitro* human colonic fermentation and a model bacterial gram-positive strain of *Lactobacillus*. The techniques that are employed are size exclusion chromatography (SEC), monosaccharide analysis, dynamic light scattering (DLS), human fecal fermentation, confocal microscopy, and X-ray small angle scattering (SAXS). This project's outcomes will enhance our knowledge about the role of DF on gut microbiota, complementing current biochemistry and nutritional studies.

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Nanoemulsion as a promising strategy to enhance the bioaccessibility of β-carotene obtained from Dunaliella salina 309

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ABSTRACT

Dunaliella salina is a unicellular halophile green microalga that is well known for the accumulation of interesting compounds being considered one of the most promising natural sources of carotenoids. The main interest for these microalgae is related to their capacity to accumulate high amounts of β-carotene that can be widely used in the cosmetic industry, the food industry, or the nutraceutical industry. To fulfil its biological functions, β-carotene needs to be bioaccessible, i.e, be released from the food matrix and incorporated into mixed micelles for absorption in the gastrointestinal tract and thus, be able to be absorbed by the intestinal cell epithelium, becoming bioavailable. A possible promising strategy to overcome their low bioavailability is the entrapment of β-carotene in nanoemulsions (NE). Due to their physicochemical and biological properties, novel ionic liquid (IL) emulsifiers synthesized using natural components have received significant attention as potential alternatives to traditional surfactants. In this regard, this study aimed the evaluate β-carotene loaded NE produced through the use of IL as an emulsifier. The NE were composed of sunflower oil (10%), 2% of extract from D. salina enriched with β-carotene (extracted under different operation conditions) and 88% of water. The NE were produced by high-intensity ultrasonication and evaluated regarding physical stability (droplet size, polydispersity index and ζ-potential) and the entrapment efficiency of β-carotene for 30 days. In addition, β-carotene bioaccessility and the behaviour under in vitro static digestion of the highly stable NE were evaluated. It was observed that the NE presented a droplet size lower than 300 nm, a polydispersity index lower than 0.3, a ζ-potential higher than | 60 mV | and a maintenance of the β-carotene entrapment during all the storage time. The results suggested that the entrapment of β -carotene into NE have great potential for incorporating and protecting it, increasing its bioaccessibility.

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P5. EMULSIONS, FOAMS, GELS FROM CLASSICAL APPROACHES TO NOVEL SYSTEMS

Antioxidant properties of thymol nanocarriers in omega-3 enriched emulsions. 6

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ABSTRACT

Thymol, a natural antioxidant derived from thyme oil, has potential applications in the food and pharmaceutical industries for producing stable and oxidation-resistant emulsions. This study focuses on investigating the impact of thymol at different concentrations on aqueous solutions of whey protein isolate (WPI; 1 % w/v) under various pH conditions. The antioxidant activity of the nanocarriers was evaluated using the 2,2-Diphenyl-1-picrylhydrazyl (DPPH) and 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) assays. Once the optimal thymol concentration was determined, emulsions were prepared by adding 1% w/v of omega-3-enriched algae oil. The emulsions were then characterized over a 10-day period by measuring their size, stability index, thiobarbituric acid reactive substances (TBARS) and peroxide value (PV) to evaluate primary and secondary oxidation products (conducted at two temperatures, i.e. 4 and 60°C).

The data acquired from the PV experiments showed that emulsions incorporating thymol exhibit a reduced peroxide content in comparison to their thymol-free counterparts following a 10-day storage period under two distinct temperature conditions. This observation is likewise evident in the TBARS assay, signifying the antioxidative efficacy of thymol on the emulsions.

This study aimed to explore the potential of thymol as an antioxidant for the emulsions stabilized by WPI nanocarriers and its effectiveness in producing stable emulsions enriched with omega-3 fatty acids.

Interfacial properties and functionality of lupin protein-pectin complexes at the air-water interface 15

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ABSTRACT

Lupin protein is a potential novel protein source to be used in food products as a stabilizer, however, its poor solubility at acidic pH limits its applications. The formation of electrostatic complexes with pectin may improve its functionality at acidic pH. Here, we investigated the interfacial properties and foaming properties of lupin protein isolate (LPI) and its electrostatic complexes with low methoxyl pectin at pH 4.0, and a ratio of 2:1, 1:1, 0.5:1, and 0.25:1. We used interfacial rheology (including shear and dilatational rheology) and AFM imaging to characterize the mechanical properties and interfacial microstructure of LPI- and complex-stabilized interfaces. We observed that LPI had a higher shear modulus than all complexes. The complexes with 0.25:1, 0.5:1, and 1:1 ratio showed a higher dilatational modulus than the 2:1 ratio and LPI. At a surface pressure of 10 mN/m, AFM images indicate that LPI formed a considerably denser interface than the complexes. At a higher surface pressure of 20 mN/m, complexes formed a comparably dense interfacial microstructure. Our results suggest, LPI may form a more glass-like interface that requires a higher shear stress to disrupt the microstructure, while complexes appear to form a thicker polymeric interface that gives those interfaces a higher resistance to compression or expansion during dilatational deformation. LPI exhibited better foamability (300%) and foam stability (54 min) than the complexes, due to the smaller particle size of LPI diffusing faster to the interface. These results provide insights into the interfacial behaviors of LPI and LPI-pectin complexes at the air-water interface and could promote their application in the food industry.

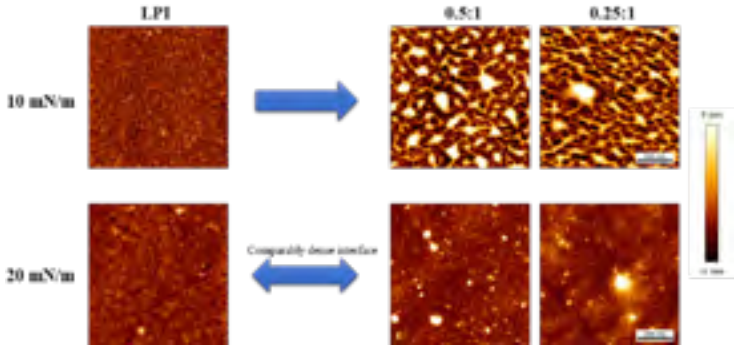

Figure 1. AFM images of Langmuir-Blodgett films prepared from LPI and lupin protein-pectin complexes at a ratio of 0.5:1, and 0.25:1. The surface pressure applied during film preparation and the scan scale used during AFM imaging were indicated on the left side.

References: Only if necessary. Should be placed at the bottom of the page and above the acknowledgments

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Conjugation of potato protein with flavonoids to influence nanostructure and emulsifying properties 22

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ABSTRACT

Designing Pickering emulsion using sustainable particles has garnered increasing research attention. A novel hybrid nanoparticle between plant-based protein and plant-derived flavonoid crystals has been fabricated and utilized to stabilize Pickering emulsions. Potato protein (PoP) and flavonoid crystals quercetin (QC) (PoP: QC mass ratio of 10: 0.1 to 10: 2.0, w/w) at pH 7.0 were used to fabricate PoPQC nanoparticles. The hydrodynamic diameter (D_h), scattering pattern via small angle X-ray scattering (SAXS), ζ-potential, protein conformation characterized by circular dichroism (CD) and fluorescence intensity were investigated. The emulsions stabilized by PoP and PoPQC were analyzed by droplet sizing, micro-electrophoresis, and microscopy across length scales. The conjugation of QC caused conformational changes in the secondary structure of PoP and fluorescence spectroscopy confirmed that QC spontaneously bound with PoP to form PoPQC particles with aromatic amino acids of PoP interacting with phenolic rings of QC mainly through hydrophobic interactions. The addition of QC had a considerable impact on both PoPQC particle size and the emulsion droplet size which increased significantly as QC increased, while the ζ -potential became more negative. Nevertheless, the emulsions were capable of maintaining their resistance to coalescence over storage for several months suggesting that hybrid plant protein-phenolic compound can help in generating hybrid nanoparticles capable of designing sustainable and biocompatible Pickering emulsions.

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Stabilization of W/W (PEG/DEX) emulsions by β-lactoglobulin nanogel particles: Influence of polymer molecular mass and nanogel size

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ABSTRACT

We presents results on the stability of W/W emulsions of incompatible aqueous polymers - polyethylene glycol (PEG) and dextran (DEX) of various molecular masses (Mw) in presence of β-lactoglobulin (BLG) nanogel particles. Mw of each polymer, particle size (Z = 30–130 nm) and pH were varied. Simple emulsion stability tests showed that the stability is appreciable only under acidic conditions (pH 3), which is presumably related to the proteinaceous nature of the nanogel. At the moment we do not have an explanation for this strong pH-effect. Further, spinning drop tensiometry (SDT) measurements were conducted.

Analysis of various emulsion formulations (pH 3) revealed a strong effect of Mw. Increase in the difference between Mw for each polymer remarkably enhances emulsion stability. On the other hand, emulsion stability is maximal for nanogels with Z = 50–80 nm (Fig. 1.). Larger or smaller nanogel particles do not stabilize the emulsions effectively, what might be associated to Z-dependent affinity to the interfacial region. SDT measurements were performed with PEG-rich droplets spinning in a reservoir of DEX-rich phase. The presence of nanogel further lowers the anyway ultralow interfacial tension (γ) of the pure PEG/DEX systems by 20–50 %. For the nanogel-free systems, γ is independent of the drop spinning velocity ω (as expected), but quite interestingly, we did observe effect of ω on the time evolution of γ for the nanogel containing systems. Up-down ω-ramps detected γ relaxations prior to leveling off at γ values that are, although weakly, but distinctly ω-dependent. This effect is further influenced by Z, being more pronounced for larger sizes. Apparently, the observed effects originate from hydrodynamic factors, but the physicochemical mechanisms ruling such behavior are not clear. In summary, the averaged γ values decrease with increasing Z (Fig. 1.). However, this finding does not correlate with the emulsion stability.

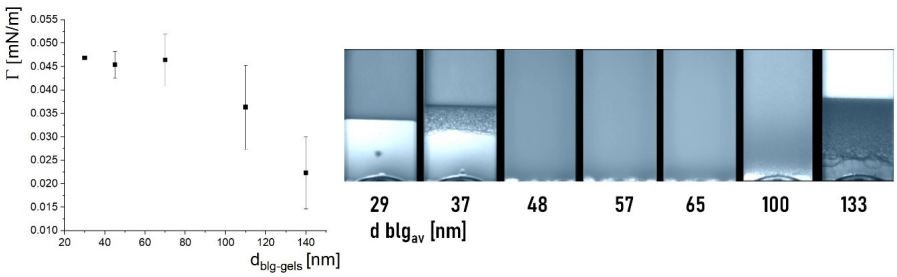

Fig. 1. (left): Interfacial tension of spinning drops, (right): Influence of the particle size on the stability of PEG10k-in-DEX75k emulsions after 40 min of aging.

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Release of anthocyanins from alginate hydrogel films coated with various macromolecules 40

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ABSTRACT

Anthocyanins are naturally-occurring phenolic compounds that act as red, blue and purple pigments, giving colour to various flowers, fruits, and vegetables, such as cherries and beetroot. They act as antioxidants when consumed in foods, helping to protect against lifestyle related diseases including diabetes, cardiovascular disease, and cancer. Following extraction, anthocyanins are vulnerable to degradation during storage and when incorporated into food products. The stability of these extracted compounds is influenced by external factors including pH, light, temperature and presence of oxygen. Formulating food products to provide the ideal stability conditions is often challenging and unrealistic, and so microencapsulation of anthocyanin extracts provides an alternative solution for maintaining stability and increasing bioavailability.

Alginate is a polysaccharide obtained from brown algae and is extensively used in pharmaceutical and biomedical applications, including producing polymeric hydrogel beads to encapsulate bioactive compounds. However, the alginate hydrogel network has a highly porous structure and this results in rapid in-vitro release of encapsulated compounds [1]. To reduce the rate of release, and increase the initial encapsulation efficiency, the hydrogel beads can be reinforced with proteins or coated with polysaccharide [1, 2].

In the search for bead formulations that can be used to retain anthocyanins in functional food products, this study used alginate hydrogel films with encapsulated anthocyanins. Fourier transform infrared spectroscopy was used to quantify the amount of anthocyanins released from alginate films with different macromolecular coatings (beta-lactoglobulin and two different types of polyelectrolyte multilayers, one comprising the naturally occurring chitosan and fucoidan polymers, and the other comprising the synthetic polymers, polydiallyldimethylammonium chloride and polystyrene sulfonate). Our results show that macromolecular coatings can improve the retention of anthocyanins, suggesting that these molecules can assist in increased delivery of encapsulated anthocyanins in alginate hydrogels.

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How bulk liquid viscosity shapes capillary suspensions 53

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ABSTRACT

Capillary suspensions are ternary liquid-liquid-solid systems where the solid particles are interconnected by liquid bridges of one fluid, all while being suspended in a second immiscible fluid. The formation of this capillary bridges network offers a new approach to structure novel food products with reduced unhealthy fat content. However, to further progress in the design of such food products, it is imperative to understand the role of liquid viscosity in shaping these suspensions.

Using experiments and numerical simulations, we investigated the effect of viscosity of the bulk liquid on the structure and rheological behaviour of capillary suspension in the pendular state. To modulate the viscosity of the bulk fluid, we employed different ratios of either dodecane and diisononyl phthalate, or silicone oils with varying chain lengths as bulk liquids. Intriguingly, rheological measurements revealed that higher bulk liquid viscosity reduces strength and flexibility in capillary suspensions, which is partly attributed to a reduced inter-connectivity of the capillary-driven percolating network. This is caused by the breakup of liquid bridges occurring at shorter distances in the presence of highly viscous bulk liquids, as indicated by numerical simulations.

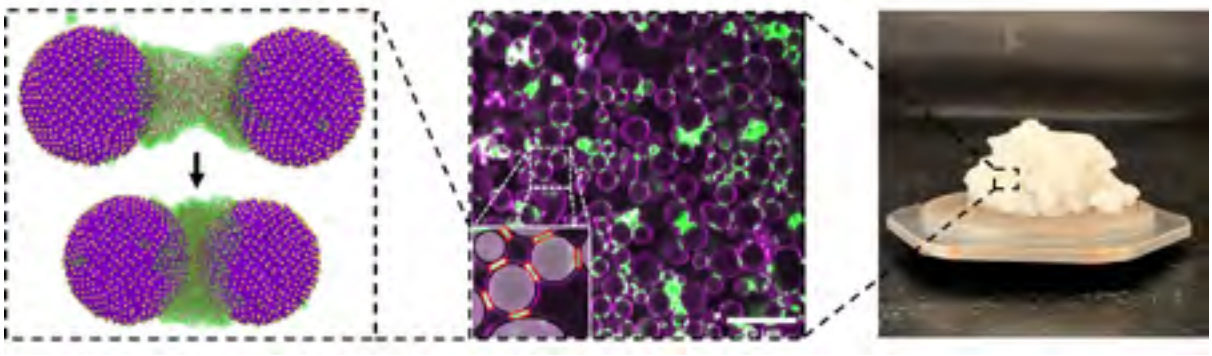

Figure 1. Capillary suspension across different scales, nano (numerical simulations, right), micro (CLSM image, middle), and macro (gel, left).

Acknowledgements: This work was financially supported by the Netherlands Organisation for Scientific Research (NWO-KLEIN, OCENW.KLEIN.303).

Towards clean-label meat and dairy alternatives: Tuning pea protein gelling properties by covalent modification with phenolic compounds 63

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ABSTRACT

Introduction: Pea protein isolates have shown inferior structuring properties as compared to animal proteins which limits their application range for plant-based alternatives to meat and cheese without using additives. Recently, the conjugation of phenolic compounds to proteins was reported to enhance the techno-functionality of some proteins [1]. The outcome was highly dependent on the phenolic compound type, the reaction conditions as well as the protein source. Gel structure formation is most relevant for meat and cheese alternatives. However, knowledge about how phenolic compound addition affects gelling capacity of pea proteins is lacking. We hypothesize that their functionality can be altered depending on the phenolic compound selected and the quantity added.

Methods: Conjugation of phenolic compounds with pea proteins was induced via autooxidation. A selection of phenolic compounds was made based on similar structural units, increasing molecular weight and hydroxyl groups, and thus their capacity to facilitate cross-links between proteins. Conjugates were prepared with fixed protein content and varying phenolic concentrations (0 – 4 mM) to study the dependency of the quantity of attached phenolic components (degree of modification) to the gelling properties. Rheology was used to study gelling properties. Changes in physicochemical properties were determined with SDS-PAGE, TNBS, Ellman's assay and solubility.

Results: Covalent attachment of phenolic compounds unto pea proteins was confirmed with the decrease in binding sites and solubility and increased phenolic concentration of conjugates (after removal of free phenolics with dialysis). This was related to increasing degree of protein modification. Confirming our hypothesis, outcomes revealed that the gelling properties of plant proteins can be altered in different ways based on the degree of modification and the type of phenolic compound used.

Overall, our findings contribute towards tuning the functionality of plant proteins with natural plant-inherent compounds for the development of future alternatives for meat and dairy.

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Emulsions stabilised via the use of mixed gels 70

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ABSTRACT

Here we investigate the contribution of cellulose microfibrils (CMFs) and a gelling protein to the stability and flow properties of emulsion gels, both before and after thermal denaturation of the protein. The concentration of each of these components is varied and the resulting emulsion gel is studied via oscillatory rheology, which we link with the microstructure via confocal laser scanning microscopy. We find that the ratio between the cellulose microfibrils and the gelling protein has a significant effect on the flow properties, which is attributed to how the structuring agents compete to adsorb to the oil-water interface. This study demonstrates how mixed gels can be used to stabilise emulsions while providing unique structural properties, making them hugely beneficial for the reformulation of certain food products.

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Gelled waters for swallowing disorders: rheological, chemical characterizations and sensory perception 78

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ABSTRACT

Many diseases can lead to swallowing disorders (dysphagia) and trigger health consequences [1]. In order to prevent the risk of penetration-aspiration, thickened fluids and gels are one of the possible options for providing water. However, the texture of these gels can still be optimized for patients, both from a sensory and/or nutritional point of view. Our aim is to characterize the structure and rheological properties of these gels in order to understand and predict sensory perception and thus to drive further formulation developments.

We first investigated nine commercial gelled waters (powder and gelled cups). We also formulated gel samples from ingredients of different sources. According to the IDDSI classification, all the samples selected belong to the same level 4, corresponding to the thickest texture for drinks [2]. We performed various shear, compression and extensional rheological tests on these samples to fully characterize their viscoelastic, slipping, flow, fracture and aging properties. To better understand gelation during cooling, we measured the kinetics by Dynamic Light Scattering (DLS). In parallel, we performed a hedonic analysis on 74 untrained healthy volunteers and a descriptive analysis using a trained panel of sensory assessors, collecting functional and hedonic features.

Despite being all 'IDDSI level-4', the commercial gelled waters exhibit rheological behaviors with viscoelastic moduli spanning over more than an order of magnitude, showing the limits of this classification. A design of experiments (about 200 formulations) allows us to observe synergies when mixing different gelling polymers, which can provide originals rheological signatures. We then discuss the correlations between the rheological behavior, especially by compression tests, and the hedonic and descriptive evaluation. We are currently formulating gels with barium sulfate to perform video fluoroscopy of swallowing by dysphagic patients.

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Effect of oil interesterification, rice bran wax and monoglyceride addition on melting, structural, rheological and stability properties of oleofoams based on sunflower and coconut oils 87

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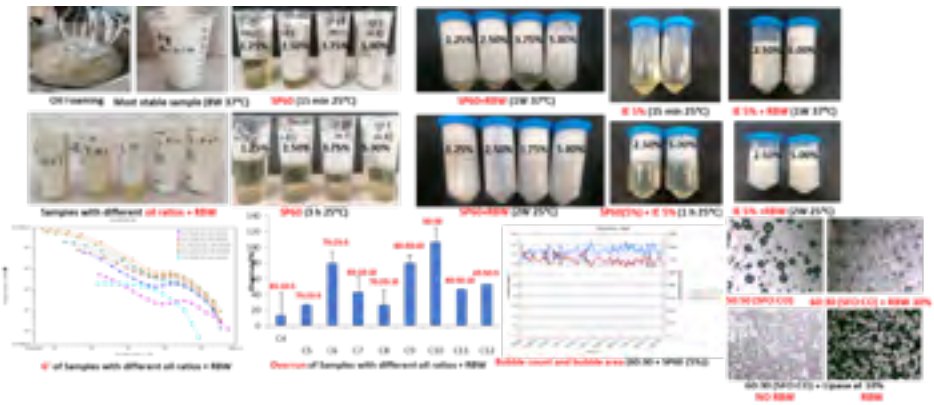
ABSTRACT

The utilization of interesterification, rice bran wax and monoglyceride was investigated to improve the stability of Oleofoams. Coconut oil (CO) contains high proportion of saturated fatty acid chains (act as crystals to stabilise the foam), and sunflower oil (SFO) which is rich in mono and polyunsaturated fatty acids hence they were utilised in this study. Oleofoams were characterised for overrun, surface tension, viscoelasticity (G' and G"), physical stability over time at 7, 25 and 37°C, hardness, stickiness, and structure using a polarised light microscope. As an initial stage, SFO and CO were mixed at different ratios and foamed. Although a high overrun was obtained, especially when high CO concentration was used, oleofoams immediately collapsed. Rice bran wax (RBW) was applied at 5 and 10% concentration to produce an oleogel before turning into an oleofoam. It was observed that increasing the formulation of coconut oil in the oil mixtures aids the crystallization rate and also improves stability as evident in the viscoelastic properties, hardness and stickiness of the foams. Including RBW, especially at high concentration, resulted in a more stable oleofoam at incubation temperature of 37°C, however with less overrun compared to the samples with no RBW. The best formula from initial trials (60% SFO:30% CO), with or without RBW was modified using further treatments to improve foamability, while maintaining stability. Immobilized form of Lipase (2.5 and 5%) was used to interesterify the oil, and sorbitan monostearate (Span 60) was investigated at 1.25, 2.5,3.75, and 5% as a surfactant. Interesterification or adding surfactant only (no RBW) resulted in immediate foam decay at 25^{0}C; only 5% surfactant was stable for up to 2 h. The inclusion of enzyme at 5% into the oil mixture containing RBW at 10% increased the overrun while also maintaining its storage stability at 37°C. Span 60 inclusion at 5% compared better to the enzyme at 5% in terms of foam stability and overrun. The modification methods applied can be promising to produce stable oleofoams for food applications.



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How to make soft Ca2+-assisted pea protein gels using mild heating? 90

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ABSTRACT

With the rising demand for plant-based protein, understanding the formation of pea protein aggregates induced by calcium is important for manufacturing of food products with appealing textural properties, since temperature alone is usually not sufficient to induce their gelation for pH > 6.0 [1]. In a former study, we have evidenced the specific influence of calcium in the microstructure of relatively strong pea protein gels formed with high temperature treatment [1]. In this paper, we dig into the unexplored question of the combined effect of calcium and moderate temperature (30 – 45°C) on the structural and rheology behaviour of calcium induced pea protein aggregates: How can we make soft (Ca^{2+}-assisted) pea protein gels using mild heating ?

The evolution of the microstructure as a function of the process applied, was studied with static light scattering (SLS), confocal laser scanning microscopy (CLSM) and fourier transform infrared spectroscopy (FTIR). Rheological properties were characterized by small amplitude oscillatory shear (SAOS) measurements.

Our results show that the particle size distribution of Ca^{2+}-induced protein aggregates shifts from the range of 100-1000 µm to 5-100 µm when increasing the temperaturefrom 30°C to 45°C, indicating important microstructural re-arrangement. Within a short to moderate holding time (0 s - 6,000 s) at maximal (mild) temperature, G' increased with temperature. This indicates that the weak inter-aggregate bonds were broken during the mild temperature increase, leading to structural rearrangement and exposing more reactive groups. Interestingly, as the holding time was extended to 60,000 s, all gels reached similar high values of G' even for the low temperature of 30 °C. Rheology results correlate well with changes in secondary structures of pea protein, whereby we observed a progressive decrease in β sheet along with an increase in β turn and the emergence of anti parallel β sheet.

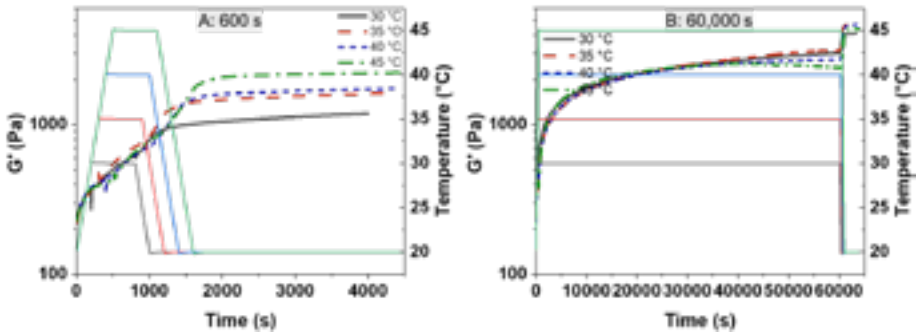

Figure 1. Storage modulus (G') values of Ca^{2+} - pea protein soft gels formed at different mild temperatures (30°C, 35°C, 40°C, and 45°C) and different holding times (600s, and 60,000s, A-B).

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Design of plant-based bigels made from agar, κ-carrageenan, sunflower wax, and monoglycerides 96

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ABSTRACT

Bigels consist of two gelled phases, namely an oleogel and a hydrogel, creating a biphasic system, which can be used as alternative structured fat or as a bioactive compounds delivery system in foods. The study aimed to develop and characterize plant-based bigels utilizing agar and κ-carrageenan in the hydrogel phase, along with sunflower wax (SW) and monoglycerides (MGs) in the oleogel phase. The hydrogel was prepared with 2% w/w agar and 1% w/w κ-carrageenan, while the oleogels were structured using either pure SW at concentrations of 6%, 8%, 10%, or 12% w/w, or a combination of MGs and SW in a 1:1 ratio at the same concentrations. To create bigels, these phases were combined in several hydrogel-to-oleogel ratios (80:20, 60:40, 60:40, and 20:80). The resulting bigels were subjected to evaluation by polarized light optical microscopy, texture analysis, liquid binding capacity measurement, and Fourier-transform infrared spectroscopy. All bigels were homogeneous and shelf-stable except for the 40:60 ratio and the 60:40 formulations containing 10% and 12% SW and MGs, which displayed phase separation. The hardness of the bigels followed the order 80:20>>60:40>0:100 and 20:80. Increased hardness was observed when MGs were present, in most cases. The results indicated that higher SW and MGs concentrations led to increased hardness in the 20:80 and 60:40 ratios, while the reverse was observed in the 80:20 ratio. Microscopy analysis revealed that higher structurant concentrations in the 80:20 ratio resulted in smaller oil droplets within the bigels. Moreover, the addition of MGs in the oleogel phase led to a more uniform distribution of oil droplet sizes. These results demonstrate the formation of stable bigels even when using low concentrations of SW and MGs, while emphasizing the effect of the hydrogel/oleogel proportions and structurant concentrations on microstructural and mechanical properties of the bigels.

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Characterizing the microstructure and physical properties of bigels incorporating agar, κ-carrageenan, candelilla wax and monoglycerides in several edible oils 97

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ABSTRACT

Bigels are biphasic systems formed by combining water-based hydrogels and oil-based oleogels. This innovative system could serve as an alternative structured fat in foods, reducing the negative health effects associated with saturated fat consumption. The aim of the study was to investigate the physicochemical properties of bigels structured with agar and κ-carrageenan in the hydrogel phase, and candelilla wax (CDW) and monoglycerides (MGs) in the oleogel phase. Various structurant concentrations and different edible oils were assessed. Specifically, hydrogels were formed using 2% w/w agar along with varying concentrations of κ-carrageenan (0%, 0.5%, or 1% w/w). Oleogels were created using three distinct formulations: i) 15% w/w MGs, ii) 15% w/w CDW, or iii) a combination of 7.5% w/w MGs and 7.5% w/w CDW in olive, sunflower, sesame, and soybean oils. Bigels were then structured by mixing the hydrogel and oleogel phase in a 80:20 ratio. The bigels were evaluated by optical microscopy, texture analysis and Fourier-transform infrared spectroscopy. The results demonstrated that an increase in the κ-carrageenan concentration in the hydrogel phase significantly enhanced the hardness of the resulting bigels. Microscopic analysis showed that higher κ-carrageenan concentrations led to larger average oil droplet sizes within the bigels. Furthermore, an increase in MGs concentration within the oleogel phase correlated with larger oil droplets in the bigels, while simultaneously reducing their hardness. In terms of using different oils, olive oil produced harder bigels, with no statistically significant differences observed in other textural parameters and microstructure. These outcomes underscore the significant impact of the hydrogel and oleogel phase compositions on the microstructural and mechanical characteristics of the resulting bigels. Overall, the formed bigels exhibited excellent stability, rendering them a promising fat substitute suitable for a wide range of food applications, including vegan products.

Acknowledgements: This research work was supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the "First Call for H.F.R.I. Research Projects to support Faculty members and Researchers and the procurement of high-cost research equipment grant" (Project Number: 3601).

Microscopic Droplet Quantification of Food Colloidal Systems 107

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ABSTRACT

Studying the microstructural arrangements of food colloidal suspension is of great importance to understand their macroscopic properties. Information about structural elements of some colloidal matrices like emulsions can be indirectly obtained with techniques like dynamic light scattering. Though, this often requires sample dilutions that compromise their structural arrangement. The microstructure of other colloidal matrices like foams are currently studied under specialized and expensive equipment. Direct visualization under microscopes gives a clearer picture of the structure of colloidal suspension, however currently they are mostly used for qualitative descriptions due to the lack of image analysis tools to convert the images to data.

Here, we have developed a machine learning algorithm that can segment droplets from microscopic images of colloidal suspensions, based on existing algorithms for segmentations of cells in microscopic images. The algorithm has been trained with experimental data consisting of dozens of microscopic images of emulsions obtained with range of different microscopy techniques, as well with theoretical data consisting of computer-generated images of droplets in colloidal suspensions generated. The algorithm has been specifically designed to segment droplets of varying sizes across the images.

The algorithm then provides data about each individual segmented droplet, including their location, size, distance to neighbor droplets, and a series of different shape descriptors, which can then be correlated with rheological parameters to advance the understanding of the colloidal suspensions (i.e., is shown how sharp edges in foam air bubbles extend the linear response to deformation compared to circular air bubbles). The algorithm can be run in a batch mode, allowing the quantification of microstructural changes of droplets in time-lapse measurements (videos will be shown). This algorithm has been developed in phyton programming language and is made available online for users and can be run as a plugin with freeware.

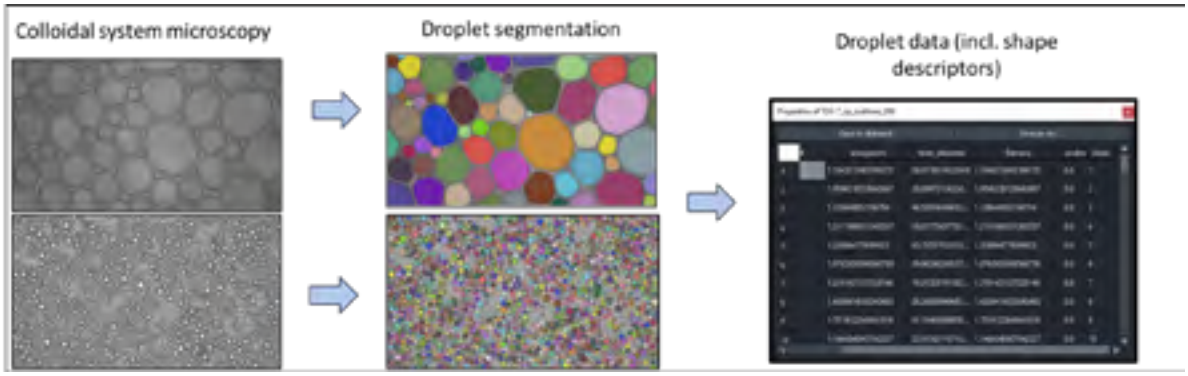

Figure 1. Segmentation and data of microscopic droplets in an egg-white foams and an emulsion

Structure, Rheological Behavior, and Foam-Stabilizing Potential of Kidney Bean Proteins at the Air-Water Interface 117

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ABSTRACT

Red kidney beans (Phaseolus vulgaris L.) are globally one of the most consumed legume crops, and an important component of human nutrition, especially because of their high protein content (20 – 30%). There is limited information available on the processing and properties of red kidney bean protein extracts. Therefore, we conducted a comprehensive study on the interfacial properties of red kidney bean protein isolate, as well as its two primary components, globulins and albumins, to elucidate their foaming characteristics.

Because of their smaller size, albumins exhibited faster adsorption at the air-water interface and produced foam with higher overrun compared to globulins. We used large amplitude dilatational rheology in combination with the general stress decomposition method to characterize the rheological properties of the air-water interfaces, and observed that albumins formed solid-like interfacial layers with higher stiffness and network density, and stronger in-plane interactions. The globulins created much weaker and more stretchable interfaces, and yielded foam with superior stability compared to the albumin fraction, possibly attributed to the thicker interfacial structure. The behavior of the whole protein mixture was dominated by the globulins. This interface was also weaker and more stretchable in comparison to the albumin interface, resulting in foam with lower overrun yet superior stability relative to albumin-based foam.

Understanding these properties is crucial for improving the use of red kidney bean proteins in various food and industrial applications.

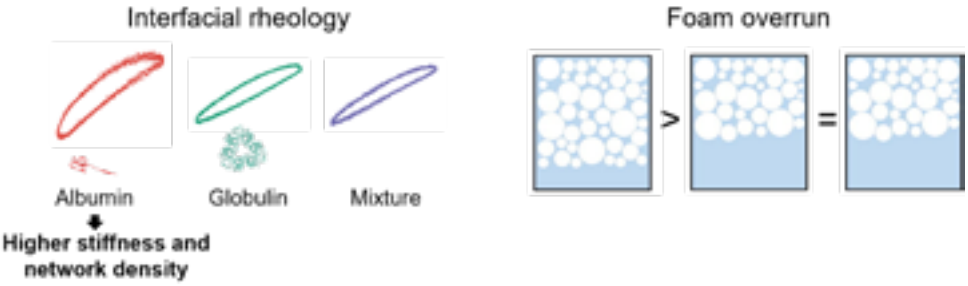

Figure 1. Interfacial rheology and foam overrun of kidney bean proteins

On the (Micro)Rheology of Lactoferrin/β-Lactoglobulin Coacervates 165

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ABSTRACT

Heteroprotein complex coacervates (HPCC) has great potential in many food applications. However, understanding the rheology-coacervate structure relationship, as well as their sensitivity to slight changes in the physicochemical environment, is still an active research topic. Herein, HPCC between two oppositely charged proteins, lactoferrin (LF) and β-lactoglobulin (βLG) was investigated. The influence of ionic strength and temperature on the rheological properties of LF/βLG coacervates was examined using oscillatory shear rheology and microrheology from dynamic light scattering. LF/βLG HPCC exhibited a liquid-like character with G′(ω) < G″(ω) and an increase of both moduli with decreased temperature but a softening effect with increased ionic strength. The dependency of G′ and G″ on angular frequency (ω) demonstrated a scaling of G″ α ω1 and a lack of terminal behavior with G′ α ω1.4. The application of time-temperature superposition (TTS) and time-salt superposition (TSS) principles allowed the prediction of the rheological properties over a wide range of timescales and temperatures below the denaturation temperature of βLG and LF. The two principles suggested that increasing temperature or ionic strength accelerates coacervates dynamics but does not affect larger-scale physics. Microrheology experiments using polystyrene-coated microspheres as tracers, allowed access to a frequency range up to (ω ~ 106 rad/s) and revealed a variable scaling of G′= G″ α ω1/2 or α ω3/4 at the high-frequency terminal regime and approaching theoretical predictions of Rouse regime and Worm-Like Chain model for polymers. In the present case, it reflected a freely draining system where hydrodynamic interactions are neglected at these timescales. By combining rheology and microrheology, we provide a comprehensive study that underscores the influence of ionic strength and temperature on LF/βLG coacervates. This study highlights the similarities and differences between protein coacervates and polymer systems and offers new insights into the microstructure of HPCC relevant to various applications.

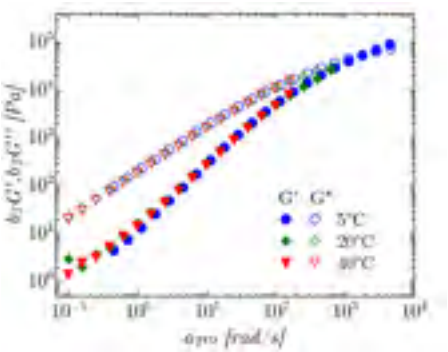

Figure 1. Time-temperature superposition master curve: Shifted Storage (G′) and loss (G″) moduli as a function of shifted angular frequency (ω) from different temperatures with a reference temperature of 20°C.

Acknowledgements: A part of this research was funded by the Regional council of Brittany and INRAE with an ARED grant n° 3525.

Emulsifying and foaming properties of Chlorella sorokiniana biomass 172

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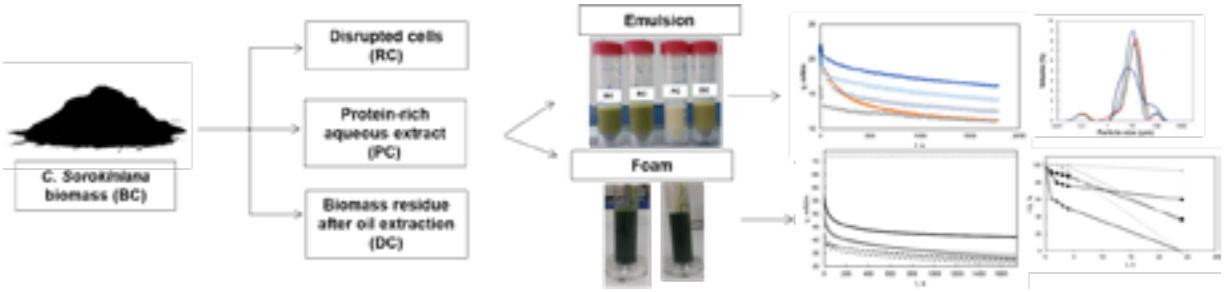
ABSTRACT

The ability of microalgae to produce high-value and surface-active compounds, including proteins, polysaccharides, glycolipids and phospholipids, makes them an intriguing source for various industrial applications such as the interfacial stabilization of emulsions and foams. Chlorella sorokiniana is a green microalga rich in protein, vitamins, minerals, and antioxidants, making it an ideal ingredient for various food applications. The current work studied the emulsifying and foaming properties of different fractions of Chlorella sorokiniana biomass namely the whole cells, the disrupted cells, a protein-rich aqueous extract of the cell disrupted biomass and the disrupted biomass residue after oil extraction. The different fractions obtained by Chlorella sorokiniana biomass were characterized in terms of the time-dependent interfacial tension at the water-air and the water–oil interfaces. For the determination of the emulsifying ability of the biomass fractions, emulsions were prepared and characterized in terms of the droplet size distribution and their morphology by Laser Diffraction and Confocal Laser Scanning Microscopy respectively. As regards the foaming properties the different fractions were characterized in terms of zeta-potential, foaming ability, foaming stability and foam morphology. The results showed that the biomass presents weak emulsifying properties whereas the type of fraction affects the emulsifying properties, the morphology and the stability of emulsions. Regarding the foaming properties the results showed that the examined fractions show interfacial activity and foaming ability. The type of fraction affects strongly the foam characteristics and its stability. Overall, the findings of the study suggest the potential for developing effective foaming agent from fractionated microalgae biomass for commercial applications.



Inhibition of lipid oxidation in soybean oil-in-water emulsions and bulk oil using acid hydrolyzed extracts of sugar beet leaves 208

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ABSTRACT

This research investigated the effects of acid hydrolysis (AH) on phenolic extracts of sugar beet greens (SBG). SBG extracts were acid hydrolyzed using 0.6 M HCl at 80 , and their total phenolic content (TPC), antioxidant activity, metal chelating activity, chlorophyll content and phenolic profile were monitored. The cupric chelating activity, TPC, and DPPH radical scavenging activity of extracts were significantly improved ($p \leq 0.05$) after AH. The chlorophyll content decreased significantly after AH. Moreover, AH disrupted the glycosidic link of phenolic compounds, causing concentrations of individual polyphenols to rise or the appearance of new phenolics such as catechin, myricetin, etc. The extracts were added to soybean oil-in-water emulsions and bulk oil to inhibit lipid oxidation. The emulsion was prepared by adding 2% (w/v) stripped soybean oil and 0.2% (w/v) Tween 20 as a surfactant to a sodium acetate-imidazole buffer (10 mM, pH 7.0). The physical properties of the emulsions were examined by assessing the distribution of droplet sizes and the zeta potential using a Zetasizer Nano-ZS apparatus. The oxidation stability of the emulsion was monitored by measuring the primary (hydroperoxide) and secondary (hexanal) oxidation products. The Rancimat method was used to measure the oxidative stability of bulk soybean oil. The emulsion containing 400 µM TPC of the control extract had the longest lag phase in oxidative stability. However, the bulk oil containing 400 µM TPC of the acid-hydrolyzed extract had the highest oxidative stability. Figure 1 shows the design of experiment of the project. The better effectiveness of acid-hydrolyzed extract in the bulk suggests that the modified phenolic composition had a more favorable impact in this lipid environment.

Figure 1. Design of experiment of the project

Acknowledgements: The authors acknowledge financial support (PhD scholarship) from Fondazione Cassa di Risparmio di Padova e Rovigo (CARIPARO).

Preparation, Rheological Behavior, and Application of Novel Dual-Structured Emulsions Made from Natural Supramolecular Gelators 209

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ABSTRACT

Dual-structured emulsions have received considerable interest due to their complex microstructures and multifunctionality. In this manuscript, we first fabricated novel glycyrrhizic acid (GA)-based emulsion gels by using the excellent interfacial properties of GA and the supramolecular self-assembly behavior of GA and sterol-oryzanol (SO) in the aqueous phase and oil phase, respectively. Small-angle X-ray scattering results showed that a GA fibril network is formed in the water phase and a SO fiber network is formed in the oil phase. The formation of these networks endow emulsion gels with an excellent storage stability, maintaining their original structure after storing for 30 days. These structured emulsions showed a homogeneous structure without SO in the oil phase, a bicontinuous network structure at 10-20 wt% SO, and a jamming structure at a higher SO concentration of 30 wt%. Small amplitude oscillatory stress (SAOS) tests indicated that the oil phase structuring by the sterols significantly enhanced the viscoelasticity of GA nanofibril emulsion gels. Moreover, the bicontinuous emulsion gels exhibited a higher elasticity than the jammed emulsion gel, as evidenced by a lower damping factor and frequency power-law exponent. The data of crossover strain, phase angle, and the normalized Lissajous-Bowditch curves from large amplitude oscillatory stress (LAOS) tests further revealed that compared to the samples in a jammed state or without oil phase structuring, the emulsion gels with a bicontinuous network showed a higher structural elasticity and thus were more resistant to large deformations. More importantly, the different microstructures might affect the release behavior of encapsulated hydrophilic/hydrophobic active substances in these dual-structured emulsions, showing a slower release in samples with a bicontinuous structure than others. These findings could potentially aid in the design of novel emulsion gels with specific textural and functional properties for foods, cosmetics, and pharmaceutical applications.

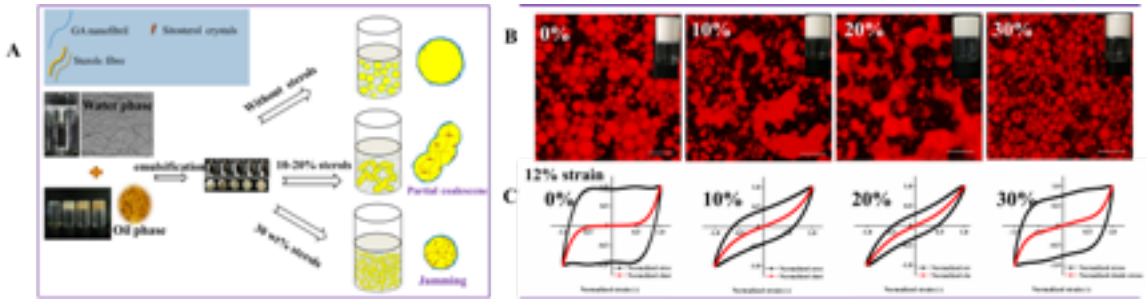

Figure 1. (A) Schematic diagram of the fabrication of GA-SO dual structured emulsions. (B) Microstructure and (C) large deformation oscillatory rheological normalized elastic Lissajous-Bowditch curves at 12% strain of GA-based dual structured emulsions with different SO concentrations (0-30 wt%) at a fixed GA fibrils concentration (4 wt%)

References: Li, Q.; Xu, M.; Xie, J.; Su, E.; Wan, Z.; Yang, X. Food Res. Int. 2021,140, 110076.

Acknowledgments: The National Natural Science Foundation of China and the Chinese Scholarship Council (CSC)

Interfacial placement of antioxidants in O/W emulsions via their covalent bonding to emulsifiers 211

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ABSTRACT

Food emulsions must be stabilized with antioxidants to prolong their storage life. In recent years, there has been considerable debate regarding the potential improvement of antioxidant action when antioxidant molecules are actually placed at the emulsion droplet interfaces. In the present work, we examine this issue using a model O/W multilayer emulsion system, in which droplets of linseed oil are stabilized in aqueous buffer at pH=4 with three successive emulsifying layers of Bovine Serum Albumin (BSA), chitosan and pectin. Epigallocatechin gallate (EGCG) is used as the model natural antioxidant. We compare the antioxidant action in these systems when EGCG is just dissolved in the aqueous phase, and when it is covalently bonded to the emulsifiers. Evaluation of antioxidant action is done by monitoring the fluorescence of Nile Red dissolved in the emulsion droplets. To effect the EGCG/emulsifier covalent bonding we use two alternative approaches. In the first [1], we connect EGCG to BSA or chitosan using an alkaline hydrolysis method. In the second [2], we use a thiol-mediated reaction to bind EGCG to pectin.

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[2] C. Liu, K. H. Bae, A. Yamashita, J. E. Chung, M. Kurisawa, Biomacromolecules 2017, 18, 3143-3155.

Impact of caffeic acid and mannitol on the anthocyanins stability of pomegranate juice incorporated in gels of different types of pectin 213

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ABSTRACT

The present study aimed to evaluate the potential interactions of different pectin types with anthocyanins (ACNs) from pomegranate juice (PJ) in gels in the presence of caffeic acid (CA) and D-mannitol (M) and thus enhancing their color stability. Low methoxyl and amidated (LMA), low (LM) and high methoxyl (HM) pectins gels were prepared under the appropriate conditions. ACNs and CA were added at a concentration of 380mg/L. The gels were stored at room temperature (rt:+25oC) and refrigerator (+4°C) protected from light, and tested during a 2 months period. ACNs were quantitated after 50 days of storage by HPLC-PDA analyses and expressed relative to week 0 (relACN50). Color retention was calculated as the quotient of a value after storage (CRt) divided by the initial reading and taken as a measure of red color. ACNs decay was assumed to follow first-order reaction kinetics and natural logarithm of the CRt:CR0 ratio was plotted against the storage period. The slopes of the lines were equated with the rate constant (k), from which half-life (t1/2) and destruction (D) values were calculated. The k values were also fitted into the Arrhenius equation and activation energy (Ea kJ/mol) was calculated. Caffeic acid's stabilizing effect was more evident when used with HM and LM pectins at rt, whereas no positive effect was observed when used with LMA pectin. The co-pigmentation of ACNs with CA explains the lower Ea in HM and LM pectins. The quantitative determination of ACNs has shown that the presence of CA favors the retention of Cy monoglucoside and diglucoside at LM pectins (Figure 1). The highest t1/2 and D values of PJ red color were achieved in LMA pectin with mannitol where the Ea was equal to zero suggesting that the color retention in this case is independent of the storage temperature.

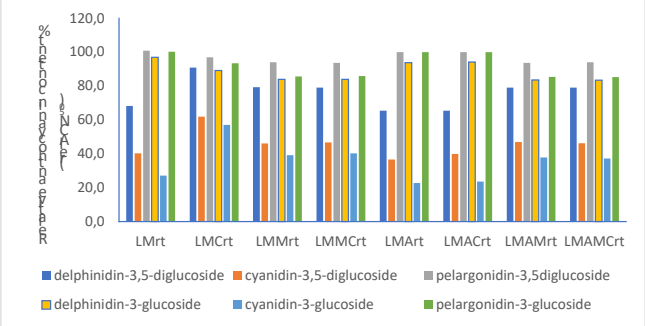

Figure 1. Relative individual anthocyanin content ($relACN_{50}$) in gels containing pomegranate juice with or without the presence of caffeic acid and mannitol after 50 days of storage at room temperature (rt) in the dark. LM: Low methoxylated pectin, LMA: Amidated LM, C: caffeic acid, M: mannitol.

Acknowledgements: The authors wish to thank Gargill in Greece for providing the pectins.

Unlocking the Potential of Novel Peas for Food Industry Applications 214

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ABSTRACT

Sustainable and nutritious protein sources are becoming increasingly essential due to a growing global population and the rising popularity of plant-based diets. Legumes, such as pea (*Pisum sativum* L.), are excellent alternative protein choices due to the overall nutritional richness of their seeds and environmental sustainability of the crop. However, the industrial application of legume-based proteins is so far limited by sub-optimal techno-functional performance. Furthermore, pulses contain antinutritional proteins, which can hinder nutrient bioavailability. This research aimed to evaluate the techno-functional and nutritional properties of proteins isolated from two distinct pea lines: a wild-type control pea and a mutant line carrying null mutations for three proteins with poor nutritional characteristics. The seeds of the wild-type and mutant pea lines were ground, and the isolated protein used to create emulsions and foams. The emulsions were characterized based on their particle size, zeta potential, microstructure, and stability over time. Additionally, foams were characterized based on their foamability and stability. To gain further insight into the surface activity of pea proteins, the pendant drop method was used to measure their surface tension and interfacial properties. The findings revealed that proteins from both pea lines effectively stabilized emulsions over a 24-hour period. Emulsion stability was observed to have a positive correlation with the following factors: small droplet sizes, high zeta potential, and specific oil and protein concentrations. Minor differences were observed in the foaming properties of the two pea protein isolates. In conclusion, this research demonstrated the similar techno-functional properties of wild-type and mutant pea lines, underscoring their potential for industrial use. Future research will utilize static *in vitro* simulation of gastrointestinal food digestion to evaluate the impact of pea mutations on starch and protein digestibility of cooked food items.

Incorporation of coenzyme Q10 in emulsion-filled gels of soy protein isolate: microstructural aspects and in vitro static digestion 219

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ABSTRACT

Although coenzyme Q10 (CoQ10) is synthesized by the human body, its production can be significantly reduced with the aging and/or endogenous production deficiency, and there can be a demand for a regular intake. CoQ10 has important roles in the mitochondrial electron transport chain, proton gradient formation in the endomembrane and the plasma membrane, in controlling the cellular redox state, as well as helping to control membrane structure. The intake of CoQ10 incorporated in foods has to consider its high hydrophobicity. The incorporation of CoQ10 into water-based products can be carried out by its encapsulation in nanoemulsions. The aim of this work was to incorporate CoQ10-loaded nanoemulsions in heat-set soy protein isolate (SPI) gels, and evaluate some microstructural aspects and the release of CoQ10 after *in vitro* digestion. The best conditions of SPI concentration and pH for gelation of non-filled gels were determined as 15% and 7.0. This condition was used to incorporate different amounts of CoQ10 loaded-nanoemulsions (25 to 95% of replacement of aqueous phase) in the gels to produce the emulsion-filled gels (EFG). EFG were characterized by instrumental colorimetry, confocal laser scanning microscopy, scanning electron microscopy and submitted to *in vitro* static digestion. Instrumental colorimetry showed all gels were highly stable after 45 days of storage, indicating the stability of CoQ10. CLSM micrographs showed the nanodroplets accumulated among the SPI microgels, possibly interacting with each other and with the protein matrix, forming a type of "emulsion network". SEM analyses indicated the more the nanoemulsion concentration, the bigger the SPI microgels forming the protein network. Regarding the release of CoQ10 during *in vitro* digestion, it increased with the amount of nanoemulsion in the gels, but after 75% of water replacement by nanoemulsion, the percentage of CoQ10 released remained the same (around 75% of the initial amount) after intestinal phase.

Acknowledgements: CAPES for the fellowship of Lais K. Jomori (Finance Code 001) and University of Sao Paulo for the fellowship of Julia M. França.

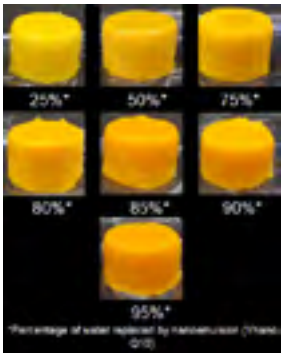

Figure 1. Visual aspects of EFG incorporating COQ10-loaded nanoemulsions, with different percentages of aqueous phase replacement.

Development of electrosprayed particles for the stabilization of food Pickering emulsions 228

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ABSTRACT

Many traditional foods (e.g., milk, mayonnaise, dressings) are oil-in-water emulsions. In addition, many lipid-enriched food products (bread, energy bars, fruit juices, soft-drinks) contain emulsified bioactive lipids (e.g., omega-3 fatty acids). In this regard, food Pickering emulsions are gaining considerable attention due to their high resistance against physical destabilization phenomena. Indeed, once adsorbed at the interface, a higher energy is required to remove the surface-active particles stabilizing Pickering emulsions when compared to conventional emulsifiers.

Food-compatible solid particles showing interfacial activity have been produced by using food ingredients (e.g., proteins and carbohydrates) through different methods (e.g., mainly solvent/precipitation methods). Interestingly, electrohydrodynamic processing is a more versatile technique allowing the production of both isotropic and anisotropic or Janus particles with advanced surface properties by mono-axial and co-jetting electrospraying processes, respectively. In mono-axial electrospraying only one solution, which might contain one or a mixture of biopolymers, is dried at room temperature by applying an electrostatic field. On the other hand, co-jetting processing implies working with two distinct solutions under laminar flow through a side-by-side geometry injector, which leads to compartmentalized dry particles.

Thus, this work aimed at investigating the development of food-grade particles by electrospraying for the stabilization of Pickering emulsions. First, isotropic particles were produced by monoaxial electrospraying using both proteins (e.g., zein) and carbohydrates (e.g., modified starch). Secondly, the processing conditions for co-jetting electrospraying were optimized to produce Janus particles by using combinations of the aforementioned biopolymers. The obtained electrosprayed particles were characterized in terms of size, interfacial adsorption and dilatational rheology. Finally, the physical stability of Pickering emulsions with omega-3 fatty acids (e.g. fish oil) was studied by determining droplet size distribution, zeta potential and creaming during storage.

Acknowledgements: This project was funded by BBVA Foundation - Leonardo Grants for Researchers and Cultural Creators 2023.

Rheological behavior of starch gels filled with curcumin-loaded Pickering emulsions 230

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ABSTRACT

Curcumin, a potent antioxidant, is poorly water-soluble and can be difficult to be incorporated in food. Emulsion-filled gels (EFG) are structured systems that combines the advantages of a dispersed oil phase within a polymeric gel matrix, and can overcome the hydrophobicity of curcumin and incorporate the bioactive in a hydrogel. This study used a Pickering emulsion stabilized by cassava starch nanoparticles and loaded with curcumin to produce emulsion-filled gels with varying emulsion amounts. Quinoa starch was employed to produce the gel phase. The rheological behavior of the EFG was assessed through small amplitude oscillatory shear tests. Linear viscoelastic regions (LVR) were determined in strain sweep tests (strain from 0.01 to 100%, frequency of 1 Hz). In oscillation frequency sweep tests (strain 0.5%, frequency from 0.1 to 100 Hz), storage modulus (G') and loss modulus (G") were obtained, and their frequency dependence was assessed. All samples fit the Power Law model well (R2 > 0.92). Rheological parameters indicated a weak gel behavior (G' > G") and an elastic behavior (tan(δ) < 0.12) for all samples. Furthermore, higher amounts of Pickering emulsion in the EFGs led to an increase in the viscoelastic (G', G") and tan(δ) moduli, indicating a higher resistance of these gels and an active filling behavior of the emulsion in the gel matrix. For the fixed frequency of 1Hz, the G1' module increased proportionally to the increase in emulsion in the formulation (500 - 3000 Pa). Furthermore, k' was always greater than k", which confirms the weak gel behavior. As the emulsion ratio increased, the values of k' and k" also increased proportionally (k' = 554 - 3057 Pa.s-n, and k" = 36 - 179 Pa.s-n), which confirms the increase in resistance and viscoelasticity for EFG with higher emulsion concentration. These findings highlight the potential applications of starch gels filled with different emulsion amounts.

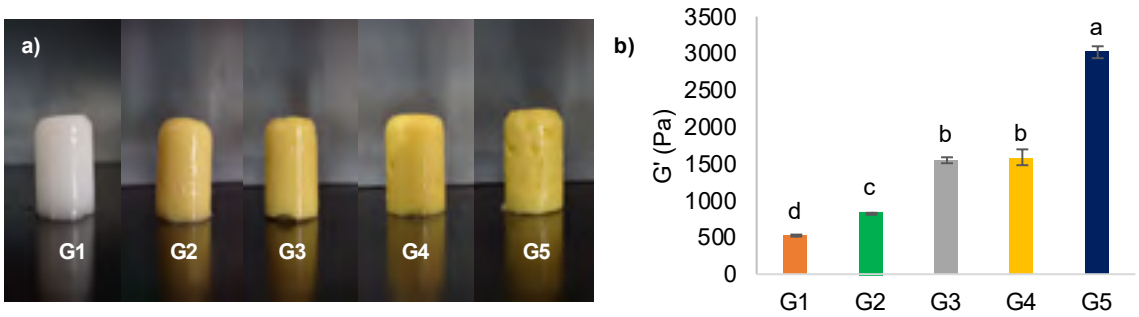

Figure 1. (a) Visual appearance and (b) Storage modulus (G') at 1 Hz of the EFG with different emulsion ratio (G1:0, G2:25, G3:50, G4:75, G5:100).

Acknowledgements: The authors would like to thank CAPES (Brazil) for the fellowship of Giselle Ramos (Finance Code 001).

Physicochemical characterization and emulsifying capacity of okra proteins 239

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ABSTRACT

This work focuses on protein isolation from okra pods (Abelmoschus esculentus) using aqueous extraction. Proteins were examined in terms of their composition, their rheological properties, as well as their ability to stabilize emulsions (oil in water). The extracted macromolecular populations were characterized using size exclusion chromatography (SEC). The isoelectric point of the extracted proteins was determined, along with ζ-potential, and macromolecular size measurements. The interfacial tension, the topology of the protein, and the composition of the of the interfacial layer were also studied. The rheological properties of the aqueous solutions of the protein concentrates were studied by shear viscosity measurements, in which the solutions displayed shear thinning, while the viscosity remained below 100mPa s at 50 s-1. Quantification of extensional viscosity and relaxation times were performed by measurements of the protein filament break up time. The properties and stability of the emulsions were investigated by creaming behavior, ζ-potential and droplet size distribution measurements, while the microstructure was visualized by confocal scanning microscopy (CLSM). The present research suggests that the extracted protein concentrates as suitable for their application in emulsification systems.

Towards hybrid protein foods: Acid-induced gels from micellar casein and pea protein mixtures 241

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ABSTRACT

For incorporating plant-based proteins in dairy foods that based on acid-induced gelation, this study investigates the gluconic-δ-lactone (GDL)-induced hybrid gels that consist of commercial micellar casein isolate (MCI) and pea protein isolate (PPI). Variations in the MCI-to-PPI (MP) ratios (3:1, 2:2, and 1:3) and the preheating methods (Route 1: preheating MCI and PPI together; Route 2: preheating them separately) impacted the physical/conformational properties of protein dispersions as well as the rheological/structural features of resulting gels. Small and large amplitude oscillatory shear (SAOS and LAOS) tests revealed that lower MP ratios led to earlier gelling point and increased the stiffness and elasticity of hybrid gels in the linear viscoelastic region (LVE). All gels shifted from elastic behavior to plastic behavior in the non-linear viscoelastic region (NLVE), and those with lower MP ratios showed reduced stretchability and faster structural breakdown. Regardless of routes, preheating (95 °C, 30 min) disintegrated the inherent aggregates/agglomerates in these commercial ingredients, showing decreased particle size but increased protein solubility, surface hydrophobicity and net |ζ-potential| value. Preheating PPI form soluble aggregates, and the presence of MCI (i.e., the preheating route 1) did not favor this process. Consequently, the mixtures with lower MP ratios and from route 2 (e.g., R2-MP31), possessed higher quantities of pea protein soluble aggregates, and formed a compact gel network with low-mobility water, as indicated by confocal laser scanning microscopy (CLSM) and Low-field nuclear magnetic resonance (LF-NMR). These findings will contribute to the use of commercial pea protein in acid-induced gel foods, such as yogurt and paneer-type cheeses.

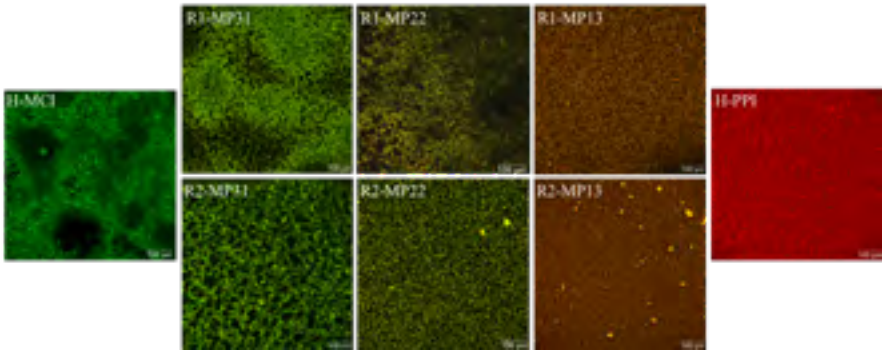

Figure 1. Microstructure of GDL-induced gels formed by H-MCI, H-PPI, and preheated protein mixtures under CLSM with 20× magnification.

Acknowledgements: This work was funded by the Danish Dairy Research Foundation and Arla Food amba.

Determining Mesh Size in Polysaccharide-Based Hydrogels 250

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ABSTRACT

This study focuses on polygalacturonate (polyGalA)-based hydrogels formed through the diffusion of divalent cations (Ca2+, Zn2+, Fe2+) from an external reservoir into a polygalacturonic solution via a dialysis membrane (external gelation method). These hydrogels exhibit varying degrees of inhomogeneity and display a substantial gradient of polymer concentration from the gel part formed near the dialysis membrane (S1) (Fig. 1) to the farthest part of the gel (S4) [1]. Using small-angle neutron scattering (SANS), we determined the mesh size in different gel slices. The nearest slice (S1) revealed a mesh size of 7.5 nm, close to the polymer's persistence length (Lp). Notably, this mesh size remained independent of the nature of the divalent cation [1]. In the farthest slice (S4), the mesh size was larger. Moreover, for Zn2+ and Fe2+, local heterogeneities were observed, possibly attributed to the association mode of the cation with the carboxylic groups of polyGalA. Molecular dynamics (MD) simulations suggested a bidentate association for Ca2+ and Ba2+, whereas Zn2+ and Fe2+ exhibited an egg-box-like coordination (monodentate association) [2]. The distribution of mesh sizes in the different gel slices was determined using fast field cycling (FFC) NMR [3]. The relaxation rates of water molecules moving between the gel fibers, interacting physically with the fibers, were closely linked to the gel's topology.

Finally, calcium-polyGalA hydrogel was employed to encapsulate beta-lactoglobulin (BLG), a globular protein from raw milk with a gyration radius of ~2.2 nm. SANS showed that BLG retained its native structure within the gel. Interestingly, the concentration of BLG was higher in the nearest part compared to the farthest sections of the gel. Moreover, the release rate of BLG proteins from hydrogels increased with the network's mesh size, varying from the bottom to the top part of the gel, with a characteristic time of a few hours [4].

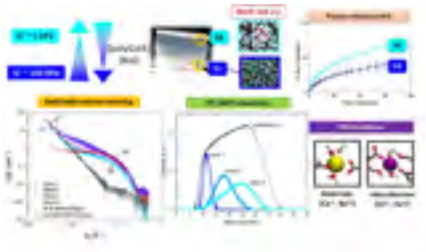

Figure 1. Ca-polyGalA gel containing a globular protein: from molecular to macroscopic length scale.

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[3.] Kogon, R. et al. Carbohydrate Polymers, **2023**. 314: p. 120922.

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Acknowledgements: Laboratoire Léon Brillouin, Synchrotron SOLEIL and Région Bourgogne Franche-Comté are acknowledged for their financial support. A part of this work has received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No 754412.

Emulsion-filled protein gels incorporating coenzyme q10 (coq10) and vitamin b12 as potential hybrid food matrices 258

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ABSTRACT

Hybrid foods are defined as food products made from mixtures of animal and plant-based ingredients, where both components are retained in the final product to various concentrations. The importance of developing this type of food matrix is urgent, as the number of flexitarian consumers has been highly increasing. Heat-set emulsion-filled gels were produced incorporating CoQ10-loaded nanoemulsions and vitamin B12 The gels were produced with 15% total protein (70% whey protein isolate and 30% soy protein isolate). The aqueous phase of the gels was replaced by 20% (in mass) by nanoemulsions. The gels were self-supported, with a very low syneresis degree. The incorporation of vitamin B12 (12.5 mg/100 g gel) weakened the protein network interactions and caused a more intense phase separation and excessive syneresis, as well as loss of vitamin B12 to the exudate. Therefore, locust bean gum was added to the gel (0.2% in mass), and the syneresis was decreased almost to zero. Also, as these protein gels are intended to produce hybrid foods, as cheese analogues, NaCl (0.4 to 1% in mass) and 0.75% (in mass) of lactic acid were incorporated in them. It was not observed weakening of the protein network or syneresis due to such additions. Regarding instrumental colorimetry, there was no difference in the parameters among the gels, as they presented very similar color intensity, color tones and Hue angle. In the uniaxial compression analysis, the gels showed very similar response under the applied force (srup), gels produced with 0.4 0.6 and 1.0 % NaCl showed lower rupture strains than gel produced with 0.8% NaCl, as well as higher elasticity modules and higher rupture stresses. Therefore, these gels can be considered as suitable matrices for prototyping hybrid foods, as cheese analogues, in the near future.

Figure 1. Visual aspect of the samples emulsion filled protein mixed gels.

Acknowledgements: The authors thank CNPq (National Council of Research and Development, Brazil) for the fellowship of Julia M. França.

Study of the antimicrobial effect of the green biocide DCOIT, encapsulated by SiO2 nanoparticles for pest protection 259

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ABSTRACT

Microencapsulated green biocide DCOIT is an effective agent for plant protection against various pathogens such as fungi, bacteria, and viruses.

The use of microencapsulated biocide DCOIT helps reduce losses from diseases and increase plant resistance to adverse conditions. Furthermore, this microcapsule has minimal impact on the environment, making it more preferable for use in agriculture.

Thus, the use of microencapsulated biocide DCOIT in agribusiness is a relevant and effective way to protect plants from diseases and pests.

In this study, the use of Pickering emulsions was of great interest, as they have the potential to obtain micro- and nanocapsules with the green biocide 4,5-dichloro-2-n-octyl-4-isothiazolin-3-one with antimicrobial properties. Polymerization in Pickering emulsions allows to produce reinforced microcapsules with unique properties.

The antimicrobial properties of the obtained micro- and nanocapsules were investistigated in this study. The effectiveness of the biocide's antimicrobial action in the micro- and nanocapsules with protective properties against pests in the selected system was determined using tests against Aspergillus niger, Aspergillus awamori, Bacillus cereus, and Fusarium verticillioides microorganisms. The storage period for observing the inhibition zone were ranged from 5 to 30 days. The inhibition of growth was determined by measuring the diameter of the microbial growth zones.

From the obtained results, it can be concluded that the use of the biocide in both free and encapsulated forms affects their antimicrobial activity. Additionally, encapsulation in micro- and nanocapsules can effectively reduce the release rate of DCOIT, thereby increasing its potential antifungal activity.

Influence of Hydrocolloids on Pea Protein Concentrate vs Isolate Performance in Simple High-Protein Plant-based Food Model 261

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ABSTRACT

The rising demand for plant-based, high-protein food products from consumers seeking to reduce their animal protein intake is evident. Plant-protein-rich fractions can be derived through either wet or dry fractionation, the latter preserving the native state of the protein and its techno-functionality. This study aimed to explore the impact of using pea protein concentrate (PPC) versus isolate (PPI), along with different hydrocolloids, on the rheological properties of a protein rich food model.

Nine commercially available hydrocolloids were tested at a fixed concentration (2%). Adjustments were made to the amounts of pea protein fraction and starch in the food model recipe to attain consistent protein (8% w/w) and starch (14% w/w) levels across all models. A small amplitude oscillatory sweep test was conducted at a constant frequency (1Hz) and temperature (25°C), with strain level varying from 0.001 to 100. Identification of the end of the linear viscoelastic region allowed measuring the storage modulus (G') within the LVR at 0.1 strain for comparison between samples.

With PPC, citrus peel pectin exhibited the highest G', followed by sugar beet pectin treated with laccase enzyme. In contrast, alginate, guar, gellan and xanthan gum, methylcellulose, and K-carrageenan formed weaker matrices. The PPI with hydrocolloids showed a different G' pattern compared to PPC. Kappa-carrageenan yielded the highest G' value, while gellan gum produced the lowest. Overall, using PPI resulted in a significantly higher G' compared to PPC in all samples except with Alginate.

This screening of the different hydrocolloid's behavior in high protein plant-based food matrices shed light on 1. How varying protein processing methods influence the rheological behavior of protein-rich food models, 2. the ability of hydrocolloid to modulate the texture strength of gel/matrices can be influenced by the process nature/ history of plant-based protein added.

Acknowledgements: This research was financially supported by the Research Council of Norway, through the project "Green Plant Food" No. 319049. Process equipment was available from the infrastructure facilities supported by the funding Food Pilot Plant Norway (296083).

Effect of Pulsed Electric Field on Characteristics of Cheese Emulsions 265

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ABSTRACT

The potential application of pulsed electric field processing as a replacement method for the use of conventional citrate- and phosphate-based melting salts in processed cheese production is evaluated. The Cheddar cheese was subjected to pulsed electric field prior to emulsification process and the consequent changes in mineral balance by ICP-MS as well as modifications in protein profile by SDS-PAGE were investigated. The colloidal properties of the obtained processed cheeses were determined by rheological measurements, particle size analyses and confocal laser scanning microscopy imaging. The findings of this study are expected to shed light on the use of green technology as a novel strategy for elimination of melting salts in processed cheese production.

Development of Polyurea Microcapsules for Encapsulation of Natural Oils 267

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ABSTRACT

Microcapsules (MCs) are used as carriers for the encapsulation of active ingredients for numerous applications, such as pharmaceutical, textiles, cosmetics, etc. Within this frame, the encapsulation of natural and/or essential oils in adequately designed microcapsules is of importance for relevant applications. Oils are chemically unstable and easily oxidized, especially when they are exposed to environmental stimuli such as light, oxygen or temperature [1]. Thus, applying proper MCs formation conditions for oil encapsulation may lead to oil protection and conservation of activity, offering simultaneously the possibility of controlled release when needed. Such systems can find applications in diverse areas, including food packaging, agriculture, etc [2].

Based on our experience on the synthesis of polyurea microcapsules for the development of coatings with self-healing abilities [3], polyurea MCs are described in the present work, consisting of a composite shell and a liquid core containing various kinds of natural oils. The microcapsules are prepared via interfacial polymerization in an oil-in-water emulsion (Figure 1), where the organic phase contains an active isocyanate monomer (MDI) and a natural oil in the presence of an organic solvent, while the aqueous phase consists of a diamine compound (DETA). The active isocyanate compound reacts with the diamine compound at the interphase to form the polyurea shell, while the natural oil (olive oil, castor oil or soybean oil) is encapsulated in the microcapsule core.

The natural oils loaded-microcapsules have been characterized through FTIR-ATR spectroscopy, SEM and optical microscopy. The morphology and sizes of the microcapsules depends on the emulsion agitation conditions. Furthermore, selective extraction was applied to determine the amount of natural oil stored in the MCs core through UV-Vis spectroscopy. Finally, the study of oil release from the core of the capsules in the presence of solvents was attempted through UV-Vis spectroscopy.

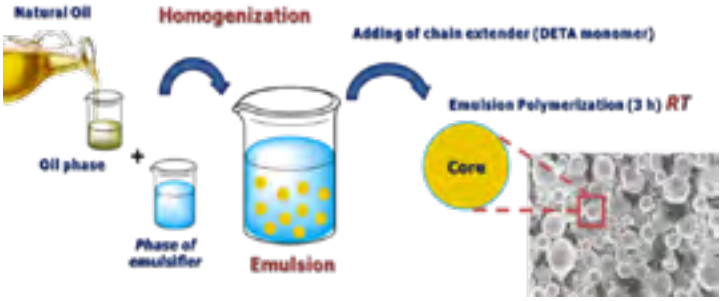

Figure 1. Synthesis of natural oil loaded- polyurea microcapsules.

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Physico Chemical Analysis of Commercially Available Natural Waxes 268

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ABSTRACT

Oleogels consist of a continuous oil phase with a dispersive oleogelator phase, enabling the oils gelation [1]. They can mimic structural properties of trans and saturated fatty acids, prevalently present within animal derived products. Hence, they qualify as solid fat substitutes for plant-based foods, by facilitating e.g., natural waxes as oleogelators. To guarantee a consistent gel quality, analysis of waxes' physico chemical nature and the influences on it is crucial. The underlying work comprises an analysis of seven different wax types (sunflower wax (SFX), candelilla wax (CLX), carnauba wax (CRX), rice bran wax (RBX), yellow and white beeswax (YBX and WBX), and orange peel wax (OPX)) each provided by the two suppliers Koster Keunen and Kahl. The following material properties were analyzed and compared in this study: Color, chemical composition, thermal behavior, and crystal structure. The colorimetry results stress the importance of a consistent purity degree, thus the relevance of the purification process. Darker waxes, expected to be rich in impurities, exhibit a finer crystal matrix compared to the respective lighter wax, as the impurities induce nucleation rather than crystal growth. Moreover, the materials origin shows an impact on the thermal behavior, chemical composition, and crystal structure. The two seed hull waxes, RBX and SFX, display a fibrous crystal matrix due to their homogeneous chemical composition. In contrast CLX, CRX, YBX, and WBX constitute a grain like macro crystallinity. The OPX samples evade most comparisons due to their low melting range and high heterogeneity. These results enable a classification of the samples into homogenous (RBX and SFX) and heterogeneous (CLX, CRX, YBX, and WBX) high melting waxes, with implications for their techno-functional parameters like oleogelation efficiency.

Figure 1. Analyzed wax samples; top: Distributor Koster Keunen; bottom: Distributor Kahl; from left to right: Sunflower wax, Candelilla wax, Carnauba wax, Rice bran wax, yellow Beeswax, white Beeswax, Orange peel wax

References: 1. Blake, A. I., Co, E. D. & Marangoni, A. G. Structure and Physical Properties of Plant Wax Crystal Networks and Their Relationship to Oil Binding Capacity. J. Am. Oil Chem. Soc. 91, 885–903 (2014).

Acknowledgements: The analyzed wax samples of this study were kindly provided by Kahl GmbH & Co. KG (Trittau, Germany) and Koster Keunen Holland BV (Bladel, The Netherlands).

Survey of Techno-Functional and Surface Properties of Different Microbial Proteins 269

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ABSTRACT

Due to the constantly growing human population, the demand for innovative protein and nutrient-rich foods is steadily increasing. Especially with regard to ecological factors microorganisms are a possible future protein source. Of particular interest in this group are microalgae and yeasts, as they have a high cultivation rate with minimal land use, while being rich in B vitamins, omega-3 fatty acids and high-quality protein. To determine the potential of microalgae and yeasts, here we present a study investigating their technofunctional properties. Nine different samples were characterized in terms of emulsion stability and capacity, gelation properties, solubility, native pH, zeta-potential and surface activity of the proteins. The results showed higher gelation properties in microalgae proteins, compared to yeast proteins. The emulsion stability of the yeast samples was strongly dependent on the extraction conditions. Very high emulsion stability was observed for the yeast protein samples extracted under mild conditions, while the stability was significantly lower for the samples treated with enzymes or heat. Within the microalgae samples only small differences in emulsion stability were observed. Emulsion capacity was similar within all samples.

The study showed significant differences between the techno-functional properties of yeast and microalgae samples. Furthermore, it was concluded that the extraction method strongly influences the properties of the protein extracts, which was attributed to agglomeration and hydrolysis of the proteins. These results contribute to the long-term food applications of microbial proteins.

Figure 1. Investigated techno-functional and surface properties of the different microbial proteins.

Acknowledgements: This research was supported by ICL Germany / BK Giulini GmbH

Plant-based ingredient blends: a comprehensive approach to model and formulating next-generation sustainable yogurts 271

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ABSTRACT

The demand for plant-based yogurts with similar nutritional, textural, and functional properties to dairy counterparts is increasing. Most of the plant-based products are formulated using one single protein-based ingredient with its formulation being dependent on other components to achieve target physicochemical and textural properties (e.g, hydrocolloids). The aim of the study is to understand, evaluate, and predict the potential of blending diverse plant-based protein ingredients (i.e., pea, oat and potato) for formulating plant-based yogurt. A full Design of Experiments along with prediction models was employed to create a combination of nine blends (3% w/w protein; 3% w/w fat; pH 6.80). Blends were characterized in terms of physicochemical properties before and after heating (85°C for 30s).

The results showed that oat-dominant blends had apparent viscosity after processing ranging from 1141 to 871 mPa.s, similar to dairy counterpart (skim yogurt had 1131 mPa.s). In contrast, potato-dominant blends had significantly lower viscosity, similar to drinkable yogurts. The pea-dominant blends showed low viscosity (3.3 to 7 mPa.s), high net values for z-potential surface charge (-37 ± 4.04), and high buffering capacity, suggesting improved colloidal stability when formulated with lipids for low viscosity products. The insights of this study and the usage of predicting models can be exploited for predicting the formulation of plant-based yogurt having selected functionality (e.g., viscosity, particle size, color, etc.) by mirroring dairy counterparts (e.g., Greek style, Kefir, Skyr, etc).

Antioxidant and Prooxidant Activities of α-Tocopherol and Black Carrot Anthocyanins in Flaxseed Oil-in-Water Emulsions 272

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ABSTRACT

With growing concerns about the health effects of artificial colorants, the demand for natural alternatives has increased. Anthocyanins from black carrots and other edible plants are common red pigments for coloring foods. However, their application in emulsions is limited by low stability. Flaxseed oil is a rich source of polyunsaturated fatty acids with numerous health benefits but its susceptibility to oxidation poses a challenge in food formulations. The aim of this study was to investigate how the combination of α-tocopherol and anthocyanins from black carrot act as antioxidants in flaxseed oil-in-water emulsions. Furthermore, the color stability of the anthocyanins was monitored over a period of 21 days. Therefore, 1% w/w flaxseed oil was homogenized in a 0.1% w/w sodium dodecyl sulfate and 10 mM citrate buffer solution (pH 4). Increasing α-tocopherol concentrations of 0 0.01, 0.08, 0.16 and 0.32 mM were added to the emulsions and 0.61 g/L black carrot extract was added to half of the emulsions. Color and primary lipid oxidation products were analyzed via spectrophotometric measurements. The formation of secondary lipid oxidation products was analyzed via GCMS. Further, lipid oxidation was determined in samples without black carrot extract to evaluate the antioxidant effect of anthocyanins.

The samples containing black carrot extract had lower concentrations of primary oxidation products ($p < 0.05$), indicating an antioxidant activity of the anthocyanins. With increasing α-tocopherol concentration, the formation of lipid oxidation products increased ($p < 0.05$), indicating a prooxidant effect of α-tocopherol (Figure 1). Simultaneously the increased α-tocopherol concentration fostered color degradation.

This study shows that anthocyanins are degraded to colorless products during lipid oxidation by acting as radical scavenger. Although α-tocopherol is known to have an antioxidant activity, it could not prevent lipid oxidation and the application of antioxidants is not suited for stabilization of anthocyanins in oil-in-water emulsions.

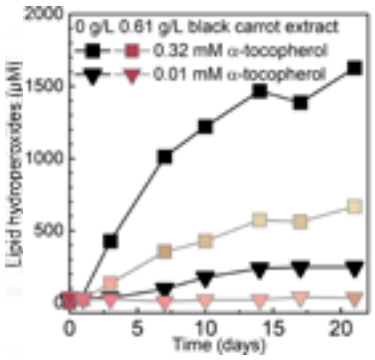

Figure 1. Formation of lipid hydroperoxides in 1% *w/w* flaxseed oil-in-water emulsions containing 0.01 mM and 0.32 mM α-tocopherol with or without 0.61 g/L black carrot extract. The error bars are within the data points and colors refer to the measured *L*C*h°* colors from the absorbance spectrum of the emulsion containing black carrot extract.

Acknowledgements: This project was supported by GNT Europa GmbH.

Small-Angle Scattering of corn, rye and wheat arabinoxylan gels 279

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ABSTRACT

Cereal bran, one of the major by-products of food production is a source of biopolymers that can be used for varied applications1. We have developed hydrogels via enzymatic crosslinking of feruloylated arabinoxylans (FAX) from wheat (WAX) and corn bran (CAX), with large potential for food and biomedical applications. The hydrogels show distinct viscoelastic properties depending on the source, and molecular structure of the FAX. Wheat and rye FAX are low substituted, whereas corn FAX shows a brush branched structure (Fig. 1a). Moreover, small- and wide-angle scattering measurements have shown differences in structure and conformation in solution and gel states of arabinoxylan of different origin. We surmise that WAX gelation is driven by ferulic acid (FA) chemical crosslinks but it has a large contribution from physical backbone interactions, as FAX is low-substituted (Fig 1b-c). Therefore, we expect that CAX and RAX gels behave differently based on their having a different substitution degree. Understanding the supramolecular interactions in the FAX hydrogels will allow us to fine-tune the gel properties and design customized materials for food, biomedical or barrier applications

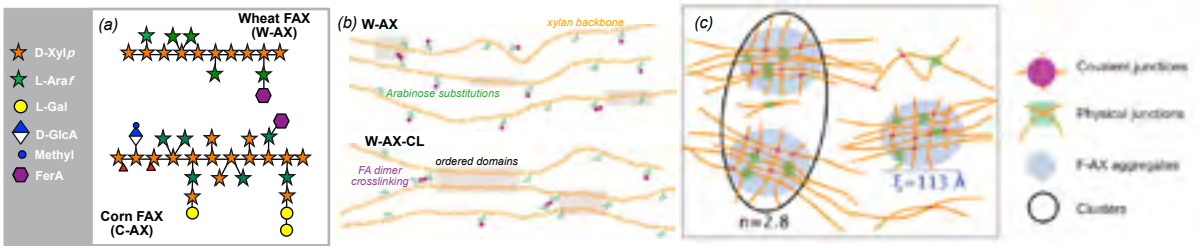

Figure 1. (a) Molecular structure of wheat and corn FAX. Proposed organization of WAX gels at b) macromolecular level and c) nanoscale network level.[2]

References: 1. S. Apprich, et al., LWT - Food Science and Technology, 2014, 56, 222-231.

2. S. Yilmaz-Turan, et al., Food Hydrocolloids, 2022, 128, 107575

Acknowledgements: This research was funded by Lantmännen and the Swedish Agency for Regional and Economic Growth

Pickering emulsions stabilized with kaolin clay particles 286

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ABSTRACT

Currently, there is increasing interest in particle stabilized Pickering emulsions, due to their wide use in the production of food products, cosmetics and pharmaceuticals. The advantage of emulsions stabilized with solid particles free from synthetic surfactants and polymers is their low toxicity, low cost, as well as high biodegradability, and high stability up to several years. Many food emulsions contain solid particles, and some cases they are recognized as the main stabilizing agents.

This work presents the results of using of clay particles from Kazakhstan Alekseevskoe deposit as emulsifiers. In the Republic of Kazakhstan, research on emulsions stabilized by clay particles is limited, while there are deposits of kaolin clay which are safe, relatively inexpensive, and affordable raw materials. In addition, the physicochemical characteristics of this clay have been well studied, and it is widely used in various industries (construction, medicine, cosmetics, food industry, etc.) due to their versatility and cost-effectiveness.

The Pickering emulsions were obtained based on kaolin clay particles at first time. The chemical composition of kaolin clay sample was carried out, the electro kinetic potential was measured and equals to – 18 mV. Clay particles form the steric barrier preventing the coalescence of water droplets. The stable emulsion was obtained at a ratio of 4 to 6 w/o by volume. The higher the concentration of kaolin clay, the higher the stability of Pickering emulsion. The smaller the kaolin clay size, the high stability of emulsions. The middle w/o ratios (4:6, 5:5) contribute to the formation of stable multiple Pickering emulsions. It was found that the addition of non-ionic surfactants Tween-20 and Tween-80 to the Pickering emulsions does not changed the stability of emulsions. Therefore, it was established that kaolin clay particles can replace the synthetic surfactants for emulsion stabilization.

Oregano oil emulsion-based coatings for food application: Impact of droplet size on Atlantic bonito (Sarda sarda) fillets' shelf-life 289

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ABSTRACT

Atlantic bonito (Sarda sarda) presents a high nutritional value and it is a fish captured in abundance along the Portuguese coast; however, it is susceptible to lipid oxidation and spoilage. Essential oils (EO) are mostly used to increase food shelf life, due their antimicrobial and antioxidant effects. Nonetheless, EO application is limited due to their low water solubility, intensive flavor, and high volatility. Therefore, emulsions may be an alternative to enhance EO dispersibility, preventing their degradation and minimizing the EO effect on sensory attributes of the food products. The droplet size influenced the EO entrapment, and the antioxidant and antimicrobial capacity of emulsions. Therefore, the effect of droplet size of oregano (OO) oil-based emulsions produced by high-intensity ultrasonication were evaluated. In order to preserve Atlantic bonito fillets quality during storage (5 °C), the selected emulsion coatings were applied to fish fillets' surface and their shelf-life evaluation were performed by pH, lipid oxidation, color, water activity, microbiological and textural analysis. The lipid phase was composed by OO (2%) individually mixed with sunflower oil at different proportions (10, 20 and 30%); Tween 80 (2%) was used as emulsifier. The physical stability (droplet size, polydispersity index and ζ-potential) of the emulsions were studied during 30 days. It was observed that the increase of lipid proportion in the emulsions (10 to 30%) resulted in an increase of droplet size (171.10 to 331.43 nm), as well as in the decrease of ζ-potential (-24.93 to -19.50 mV). The results suggested that the EO emulsion-based coatings could be used as natural preservatives of the fish quality and they extend the Atlantic bonito fillets' shelf-life.

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Bigels of food grade as potential materials for extrusion-based 3D food printing 291

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ABSTRACT

In recent years, among the most recent approaches to novel food gel systems, highlight the bigels, or hybrid gels, semi-solid structures with unique and versatile properties. Besides their classical role as carrier and target delivery vehicles for bioactive biomolecules, bigels may also be valuable tools for building complex food structures, demonstrating successfully used as material for 3D-food printing. Among the promising bioactive compounds for application as functional ingredients are chlorophylls, justified by their unique structural chemical properties. Considering these aspects, our main objective was to develop novel functional food-grade bigels with the incorporation of natural chlorophylls for application in 3D-food printing. Our objectives extended to understanding the ratio of hydrogel:oleogel fractions and chlorophyll concentration in bigel structures, through their microstructural properties, rheological characteristics, molecular properties, texture profile and color improvement. The bigels were prepared using a mixture of oleogels with carnauba wax, sunflower oil, and lecithin, and hydrogels with agar and xanthan gum in different proportions under temperature control. Functional extracts obtained from the cyanobacterium Arthrospira platensis were considered for the addition of natural chlorophylls in two different concentrations. Microstructural observations indicated that as the hydrogel:oleogel ratio was changed, clear transitions in the type of bigel formulated were observed. For all bigels, the rheological analyzes showed that regardless of the hydrogel:oleogel ratio, they were more solid than liquid and exhibited noticeable shear thinning, which allowed the printing of all bigels. The printing performances, dimensional variability, surface quality, and reproducibility of the printed models were improved with increasing oleogel concentration. In addition, the increasing the concentration of oleogel with the highest concentration of chlorophylls resulted in a more intense coloration in the bigels and improvement in the texture profile and viscoelasticity of bigels. These findings contribute to understanding and advancing knowledge of functional bigel formulations with potential applications for 3D-food printing technology.

Acknowledgements: This work was supported by the São Paulo Research Foundation (FAPESP) [grant numbers 2021/02692-3, 2021/13567-5, and 2023/02202-1].

Fine-tuning carotenoid-enriched bigel formulations: exploring the influence of oleogel: hydrogel ratio on rheological properties and 3D food printing 294

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ABSTRACT

3D printing technology is expanding and reinventing the food industry, offering unique and specific food characteristics, as well as personalized nutrition to fully meet the consumers' food desires. Bigels, as a novel semi-solid biphasic system, can be used as a food material formulation for 3D printing. Carotenoids, yellow-orange natural pigments, can be applied in bigels to enhance their nutritional properties. In this study, edible bigels with carotenoid incorporation were obtained, characterized, and 3D printed. Bigels were produced by high-speed mixing of sunflower-based oleogel and agar-based hydrogel at a controlled temperature employing different oleogel (OG): hydrogel (HG) ratios (40:60; 60:40; 80:20). Carotenoid extracts from pequi were added (800 µg/100g) in oleogel fraction. Rheological results showed a thixotropic behavior, with evident hysteresis loops between up and down curves, considered a desirable characteristic for 3D printing due to the ink's easy capacity to extrude and support its weight. The addition of carotenoids led to an increase in the apparent viscosity for bigels with a lower amount of oleogel (40% and 60%), and an opposite effect for systems with the highest amount of oleogel (80%). The comparison of the samples indicated that the increase of oleogel concentration led to an increase in G' value, indicating that OG is mainly responsible for bigels' structure. A leaching test was performed and both oil and water were contained in the leached liquid from the bigel. However more than 98% of leached liquid came from the aqueous phase, and the higher the oleogel concentration higher the liquid leached. In terms of 3D printing capability (Figure 1), the bigels showed good formation stability (inverted tube test), good printing quality, and layer deposition with high support. These results guided the development of bigels systems that can be applied for food 3D printing.

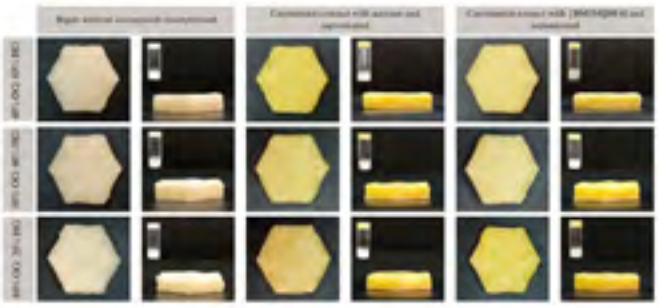

Figure 1. Bigels printability, visual characteristics, gelling, and stability through the inverted tube test at room temperature after 12 hours. Each line represents an OG: HG ratio of 40:60; 60:40; and 80:20, respectively. From left to right: bigel without carotenoid incorporation, bigels incorporated with acetone carotenoid extract, and bigels incorporated with [BMIM][BF4] carotenoid extract, respectively.

Acknowledgments: This work was supported by "Fundação de Amparo a Pesquisa do Estado de São Paulo - FAPESP" through fellowship (2021/00596-7) and grant (2021/02692-3).

Adsorption Layer Properties and Foam Behaviour of Whey Protein Isolate (WPI) Modified by Different Types of Vacuum Cold Plasma (VCP) 300

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ABSTRACT

Vacuum cold plasma (VCP) is a novel non-thermal processing technology and used to modify the physicochemical properties and functionalities of food materials. VCP was applied to whey protein isolate (WPI) at low pressure using different types of gases (air - AVCP, combination of argon and air - ARAVPC, and sulfur hexafluoride - SF6VCP). The treatment led to a decrease in the sulfur content and an increase in the carbonyl content, evidenced by oxidation reactions and enhanced disulfide bond formation, as well as cross-linking of protein molecules [1]. The foaming and dynamic surface properties (dynamic surface pressure and surface dilatational properties) of the native as well as modified WPI samples were studied. The surface dynamic properties of the adsorbed WPI layers were measured with an automatic pendant drop tensiometer (PAT1, SINTERFACE Technologies, Germany) and the surface thickness by ellipsometry (Multiskop, Optrel, Germany). The foamability and foam stability of the aqueous solutions of the WPI samples were measured by a Bikerman type of experiments sparging gas via a porous plate into a glass column and measuring foam height and drainage rate (Foamscan, Teclis Scientific, France). The kinetics of adsorption and surface dilational visco-elasticities of VCR modified WPI (see Fig. 1) are increased while the equilibrium surface pressure isotherms of all samples were similar. The ability of the protein to form a foam was only weekly affected by low-pressure plasma, while the treatment with air and SF6 decreased the volume of foam.

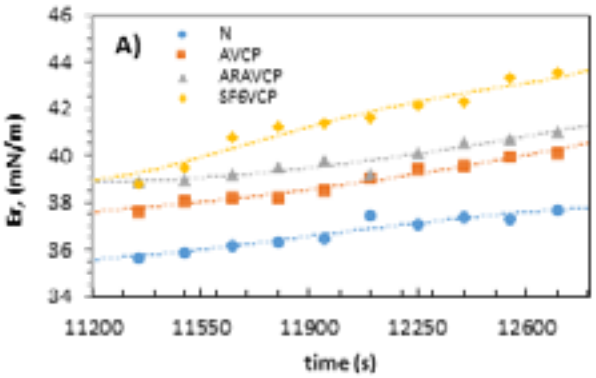

Fig. 1 Dynamic surface dilational elastic modulus Er at a fixed frequency of 0.16Hz and an area oscillation amplitude of 7% for different VCP treated WPI solutions each at a concentration of 0.1 mg/mL

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Towards Green Nanotechnology: Chamomile-Natural Deep Eutectic Solvent extract for the development of nanocomposite alginate-silver nanoparticles hydrogels 302

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ABSTRACT

Silver nanoparticles (AgNPs) are widely used in various biomedical applications due to their antimicrobial activity. In the present work, AgNPs were synthesized using a green methodology and were incorporated in alginate hydrogels. A task-specific Natural Deep Eutectic Solvent (NADES) consisting of the natural products glucose and lactic acid was used as a solvent to extract bioactive phytochemicals from chamomile flowers and the as-obtained extract was used as (a) a crosslinking agent to prepare alginate hydrogels and (b) as a reducing agent for the preparation of AgNPs.

The swelling ability and water retention capacity of the nanocomposite hydrogels were measured by soaking the hydrogel in a phosphate buffer (pH=5.5). The alginate nanocomposite hydrogel reached a swelling ratio of 868% after 10 min. The water retention remained over 60% after keeping the swollen sample in the buffer for 2 h. The average size of the formed AgNPs was found 117.9 ± 2.7 nm and their concentration was 7.0*107 ± 7.9*106 particles/mL. The antimicrobial activity of the synthesized hydrogels was evaluated against Gram-negative and Gram-positive foodborne pathogens (Escherichia coli, Salmonella Typhimurium, Listeria monocytogenes, Staphylococcus aureus and Bacillus cereus by automatic turbidometry with Bioscreen C. The nanocomposite hydrogels containing AgNPs as well as the hydrogels containing only the chamomile-NADES extract showed significant antimicrobial activity against all tested bacteria. Escherichia coli was the most sensitive to the nanocomposite hydrogels, showing 85.6 % inhibition of growth rate. Moreover, Staphylococcus aureus growth was inhibited by 47.8%, whereas the least sensitive was Bacillus cereus (15.0%).

Tribological Behaviour of Olive Oil-Based Emulsions Stabilised with Pea Protein Isolates 304

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ABSTRACT

The tribological behaviour of oil-in-water emulsions formulated with pea protein isolates (PPI) and olive oil was investigated, considering the influence of different phase volumes, dispersion degrees and phenolic content. To achieve this, emulsions with increasing phase volumes (ranging from 0.1 to 0.5) were homogenized under standardized conditions using high-pressure homogenization at 150 MPa for 5 cycles. Subsequently, attention was focused on selected samples, specifically those with 0.2, 0.3, and 0.5 phase volumes. These samples underwent processing under both standardized and optimized conditions, adjusting pressure and the number of cycles through the valve to achieve a comparable dispersion degree (dx90).

In the final phase, the systems were formulated with a phenolic-rich extra virgin olive oil (EVOO) and a mixture (50:50, EVOO-Refined olive oil) to get emulsions with different total phenolic content. The following determinations were carried out: droplet size distribution, optical microscopy, flow behaviour and tribology. Both phase volume and dispersion degree impacted on the tribological response of the olive oil-based dispersions. When emulsions with same phase volume were formulated with olive oils with different phenolic contents and processed in order to get comparable dx90, the friction behaviour was significantly affected, likely due to their ability to affect the oil/water interfacial properties. In-depth investigations are required to comprehend the mechanism underpinning the effect of olive oil phenolic compounds on the properties of oil/water interfaces stabilized by pea proteins and, in turn, their impact on emulsions tribological response and sensory perception.

Acknowledgements: This research was founded by the European Union – Next Generation EU. Project code: ECS00000041; Project CUP: C43C22000380007; Project Title: Innovation, digitalization and sustainability for the diffused economy in Central Italy – VITALITY.

Gelation of Arabinoxylan Extracted from Corn Bran at Different pH Conditions for Food Applications 305

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ABSTRACT

Corn bran comprises a significant portion of waste generated from industrial processing of corn. This by-product is comprised primarily of polysaccharides, of which roughly 30-50% of the total content is made up of arabinoxylan [1]. This makes it the most abundant dietary fibre within the bran and a crucial target for the valorisation of the corn bran, particularly in the development of new materials, such as hydrogels. The structure of corn bran arabinoxylan is heavily substituted compared to those found in other grain brans, resulting in a higher degree of ferulic acid substitution. The benefits of arabinoxylan as a dietary fibre are further promoted by these phenolic groups as they enhance prebiotic and antioxidant properties while simultaneously serving as the foundation for via enzymatic crosslinking and gel formation [2][3]. Therefore, when extracting arabinoxylan from corn bran for the purpose of gelation it is vital to select a method which retains these ferulic acid moieties. Subcritical water extraction, utilising water at high pressures and temperatures, has been shown to be effective in separating out the desired arabinoxylans, while preserving their phenolic substituents. During the extraction process however, the release of acetyl substituents can lead to acidification of the extraction solution and potential hydrolysis of the polysaccharide [4]. An investigation into the effect of extraction pH on the gelling properties of extracted arabinoxylans would be immensely beneficial in the fine-tuning of the structural and nutritional properties of the final gel. The structural gelation properties will be evaluated through investigation into gelling times, phenolic content pre- and post-gelation, molecular weight with viscosity, rheology and finally utilisation of laccases with varying activities towards ferulic acid. The production of gels sourced from waste corn bran arabinoxylan would provide novel food ingredients with prebiotic and antioxidant properties, while simultaneously upscaling a currently underutilised agricultural side stream.

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Effect of high-pressure homogenization treatments on pea proteins gelling properties: a case study on a model spreadable plant-based product 306

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ABSTRACT

This study investigates the impact of high-pressure homogenization (HPH) at varying intensities (60 and 150 MPa, for 5 cycles) on the gelling properties of a commercial pea protein concentrate suspensions (10%-15%-20% w/w) for the formulation of emulsion-filled gels, serving as a model for spreadable plant-based products. Mechanical characteristics of resulting heat-set gels were evaluated through rheological measurements. Subsequently, emulsion-filled gels were produced from a common primary o/w emulsion, with the addition of either native or treated pea protein suspensions. Characterization included frequency and amplitude sweep tests, back extrusion, texture profile analysis (TPA), and confocal laser scanning microscopy (CLSM).

HPH-treatments significantly influenced the aggregation state of protein suspensions, reducing the particle size of ~40% with the application of 60 MPa-treatment, while leading to the formation, with the application of 150 MPa, of new aggregates that, however, were smaller when compared to the native protein. Frequency sweep profiles confirmed that protein concentration is a key factor for the formation of a stiffer gel but also revealed that gels with comparable mechanical properties could be obtained with lower amounts if pea proteins were preliminarily submitted to high-intensity HPH-treatment (150 MPa). Thus, in such conditions, stronger, stiffer, more elastic and compact gels were obtained irrespective of the protein concentration in the systems, whose structure was maintained for product long-preservation, as confirmed by frequency sweep, back extrusion, and TPA tests. Moreover, amplitude profiles showed the transition to a creamy and viscous structure during its use, facilitating the spreadability of the product into a uniform and homogeneous layer. Furthermore, CLSM micrographs confirmed the formation of a more structured and compact gel matrix with increasing applied pressure.

These findings could have implications for the development of spreadable plant-based products, showcasing the potential of HPH in tailoring the rheological properties of pea protein gels for improved product formulation.

Acknowledgements: This research was funded by the European Union – Next Generation EU. Project Code: ECS00000041; Project CUP: C43C22000380007; Project Title: Innovation, digitalization and sustainability for the diffused economy in Central Italy – VITALITY.Inizio modulo

Effect of some polyphenol rich extracts obtained from forest berry with antioxidant potential on linoleic acid emulsion 314

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ABSTRACT

Non-nutritive natural plant secondary metabolites, polyphenols are a large family of compounds widespread in the plant kingdom. They are found mostly in leaves and fruits. Polyphenols have a variety of biological and chemical activities in vitro and in vivo. Among the most important classes of polyphenols are flavonoids and phenolic acids. Forest berry leaves present higher concentrations of polyphenols, for some, greater than in the fruits. This study aimed to emphasize the anti-peroxidation activity of forest berry leaf extracts on the linoleic acid emulsion model.

In this study, air-dried forest berry leaf parts of Cornelian cherry (Cornus mas), Rose Hip (Rosa canina), Blackberries (Rubus Rubus), Elderberry (Sambucus nigra), Raspberry (Rubus idaeus) and Chokeberry (Aronia melanocarpa) were powdered and extracted with 60% ethanol (v/v). Spectrophotometric methods were used to estimate the total polyphenols content and total flavonoid content of the ethanolic extracts. The ethanolic extracts were investigated for antioxidant activity in the linoleic acid emulsion system. The progression of the oxidation processes was monitored at 20 °C, 40 °C and 80 °C for 7 days by measuring conjugated dienes, hydroperoxides and thiobarbituric acid reactive substances (TBARS) formation. The investigated leaf extracts exerted protection against lipid peroxidation on the linoleic acid model. The levels of primary and secondary lipid peroxidation products were expressed as inhibition percentages, compared to negative control containing no antioxidant and positive control containing gallic acid as an antioxidant. Forest berry leaf extracts showed antioxidant activity on the linoleic model compared to positive control. The results encourage the use of forest berry leaves as an additive for feeding laying hens.

Acknowledgements: This work was supported by the Romanian UEFISCDI project PN-III-P2-2.1-PED2021-2001, no. 631PED/2022.

The effects of length distribution of the MHC and its fragments on fracture strength of fish meat gel 315

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ABSTRACT

Fish meat gel, also known as 'surimi gel,' which includes products like crab sticks and fish sausages, is consumed worldwide. The dispersed proteins in fish meat sol form a gel network through both enzyme-catalyzed and non-enzyme-catalyzed polymerization upon heating. Numerous studies showed that the myosin heavy chain (MHC) is a key protein for achieving fish meat gel with higher fracture strength. It has also been revealed that degradation of MHC caused lower fracture strength; however, the effects of the length distribution of the MHC and fragments on the fracture strength of fish meat gel is unclear.

This study explored the relationship between the polymerization of MHC fragments in deep-sea bonefish (Pterothrissus gissu) surimi and its fracture strength. Previous studies have reported that gel disintegration in P. gissu surimi is induced by heating at 35 °C [1-3]. We firstly compared the P. gissu surimi gels prepared through sequential heat treatment at 35 °C for 0 or 60 min, followed by 85 °C for 0-20 min. We additionally examined the effects of E64, a cysteine protease inhibitor, on the P. gissu surimi gels prepared under similar conditions. The results indicate that the gel disintegration at 35 °C can be prevented by the addition of E64. On the other hand, SDS-PAGE analysis revealed that the addition of E64 does not completely prevent the increase in the MHC fragments. Combining the changes in fracture strength with the SDS-PAGE separation patterns of each gel suggests that the rate of thermal polymerization varies according to the length of MHC or its fragments. The polymerization of short MHC fragments at high temperatures (approximately 60 °C) causes disintegration in P. gissu surimi gel. Consequently, a broader length distribution of MHC and its fragments results in lower fracture strength of P. gissu surimi gel.

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Starch–lauric acid complex-stabilised Pickering emulsion gels enhance the thermo-oxidative resistance of flaxseed oil 316

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ABSTRACT

Hydrophobically modified starch complexes have the potential to form Pickering emulsions and improve the oxidative stability of flaxseed oil. Here, V-type starch–lauric acid complexes (SLACs) were fabricated via solid encapsulation within 0.5–12 h and applied in flaxseed oil Pickering emulsions. Complexing index, X-ray diffraction, and differential scanning calorimetry analyses confirmed that the degree of complexation increased with the reaction time. Pickering emulsion gels stabilised by SLACs generated with reaction times of 6 h and 12 h exhibited good storage stability and high yield stress, G′ values, and apparent viscosity. Confocal laser scanning microscopy and cryo-scanning electron microscopy revealed a gelation mechanism involving increased interface roughness and enhanced droplet–droplet interaction. In comparison to pure flaxseed oil, a higher thermo-oxidative resistance was observed at 130 °C, with a markedly longer time to oxidation induction for emulsions and emulsion gels stabilised by SLACs. Our findings could assist in the design of hydrophobically modified starch and provide a new paradigm for delaying oil oxidation.

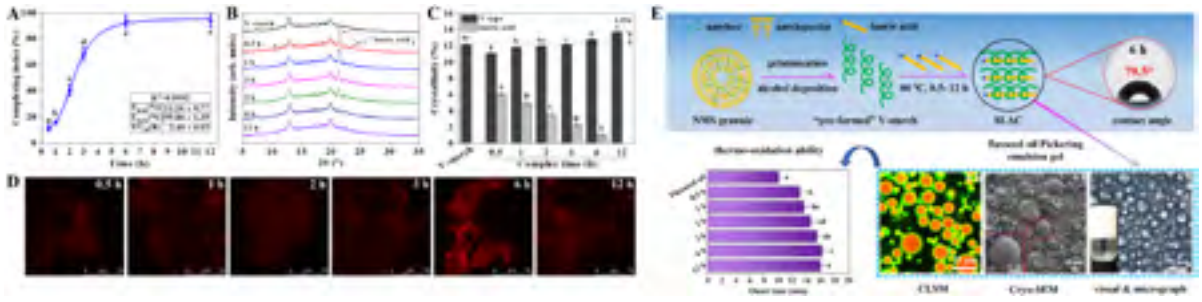

Figure 1. (A) Kinetic curve for the complexing index of SLACs. (B) X-ray diffraction patterns of V-starch and SLACs. (C) Relative crystallinity analysis of V-starch, SLACs and lauric acid. (D) Confocal laser scanning microscopy images of SLACs. (E) Schematic diagram of the fabrication of SLACs, emulsion behaviour and oil thermo-oxidation evaluation. Different superscript letters (A–E, a–e) denote statistically significant differences ($p < 0.05$). SLACs, V-type starch–lauric acid complexes, where 0.5–12 h denotes SLACs prepared with complexation times ranging from 0.5 to 12 h.

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Understanding the Compatibility Between Soluble Fiber and Casein for the Development of Functional Foods 319

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ABSTRACT

Consumption of soluble fiber such as oat β-glucan may reduce cholesterol, prevent cardiovascular disease risk, and normalize blood sugar levels. In combination with milk proteins, it makes beverages healthier. β-glucan as a stabilizer increases the viscosity and improves the texture and mouthfeel of food beverages. Additionally, it meets the current consumer trend which demands "clean label" or the use of functional natural plant-derived additives. A previous study showed that beverages containing 15-25 g casein and 2-3.5% oat β-glucan without stabilizers (mono-di-glycerides, dipotassium phosphate, and -carrageenan) separated into two phases, one mostly casein and the other mostly polysaccharide β-glucan. The objective of this study was to investigate the compatibility conditions between micellar casein and β-glucan that cause separation in beverages. Nine solutions of biopolymers with 1.2-2% β-glucan and 4-6% casein were prepared and pasteurized at 73 oC/15 seconds and retort sterilized at 121 oC/5 minutes. The solutions' stability was calculated by % of the total volume of the upper phase, the biopolymer concentrations (BC) for phase separation via particle size distribution, and dynamic light scattering (DLS). The experiment was a full factorial of two factors with multiple levels each. The critical total BC increased from 6.75% to 7.8% as the temperature increased which reduced the sample stability to 28%. Higher temperatures increased the stability since all sterilized samples had a stability higher than 90%. DLS showed aggregate formation because increasing β-glucan concentration increased the mean particle size from 300nm to 1.8μm. Therefore, these findings suggest that segregative phase separation occurred due to limited biopolymer compatibility. Thus, decreasing BC increased the solution stability, and increasing the thermal treatments from pasteurization to retort sterilization produced stable solutions with smaller particle sizes and low concentrations as shown by DLS.

Mimicking the melting profile of adipose tissue through a controlled coalescence in HIPEs 328

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ABSTRACT

Plant-based adipose tissues are the next step towards improving meat analogues. The morphology of adipose tissue - adipocyte cells densely packed in a network of cell membranes and collagen – can be seen as a packed emulsion, also referred to as HIPEs. When such packed emulsions are stabilised by a network of yellow pea (Pisum sativum), a soft-solid material, visually similar to adipose tissue, is obtained [1]. However, the challenge of these systems is to mimic the complex melting behaviour of adipose tissue. In this study, we aimed to investigate the melting properties of HIPEs with different oil types; rapeseed oil and coconut oil. Packed emulsions were made at temperatures above the melting point of coconut oil. Oscillatory shear rheology showed that emulsions with rapeseed oil showed a much lower gel strength (elastic shear modulus) than adipose tissue and no melting properties were obtained. However, when coconut oil was used, a similar gel strength was obtained as the adipose tissue at ambient temperatures, due to the crystallisation of the oil. When temperature was increased, the modulus decreased to represent the melting process. In addition, the gel strength was weakened at higher temperature, to values even lower than the HIPE with rapeseed oil, suggesting a weakening of the pea protein network after crystallisation. The limited protein coverage (<47%)[2] of the o/w interface might allow lipid crystals to protrude into the continuous phase. Subsequent melting could cause coalescence with adjacent droplets and emulsion destabilisation. Using laser diffraction, coalescence was confirmed for packed coconut emulsions after crystallisation, while the particle size was similar to packed rapeseed oil emulsions before crystallisation. With this work we have shown that incorporating coconut oil in a packed emulsion system yields a melting profile, and can be used to influence the strength of the pea protein network.

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Self-assembling peptide hydrogels with encapsulated porphyrin chromophores are anti-infective and biocompatible and display antimicrobial efficiency 331

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ABSTRACT

Antimicrobial resistance (AMR) poses a significant global health risk as a consequence of misuse of antibiotics. Owing to the increasing antimicrobial resistance, it became imperative to develop novel molecules and materials with antimicrobial properties. Porphyrins and metalloporphyrins are natural chromophores which present antimicrobial properties especially after irradiation. As a consequence, porphyrinoids have recently been utilized as antimicrobial agents in antimicrobial photodynamic inactivation in bacteria and other microorganisms. Herein, we report the encapsulation of water-soluble porphyrin photosensitizers into self-assembling peptide hydrogels which serve as delivery vehicles, namely hydrogels formed by the well-studied fluorenyl-methoxycarbonyl-Phe-Phe dipeptide. We found out that these hydrogels are cytocompatible and upon irradiation display antimicrobial efficiency against both Gram-positive S. aureus and Gram-negative E. coli bacteria with the zinc porphyrins being more efficient [1]. We have recently demonstrated that delivery of encapsulated porphyrins into Fmoc-Phe-Phe hydrogels accelerated the healing of experimental skin defects in vivo [2]. The combination of a cytocompatible and anti-infective hydrogel scaffold with the antimicrobial efficiency of metalloporphyrins, in combination with their wound-healing potential creates a potent formulation for topical applications. We propose that these hydrogels present a promising alternative for combating bacterial infections in the face of growing antimicrobial resistance concerns.

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Olive Oil-Water Emulsions Stabilized by Apple Pomace used as a Solid Fat Substitute in Biscuits 333

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ABSTRACT

Fat is essential for taste and texture in baked goods, but common solid fat raw materials used in baked products (e.g., shortenings, margarine) pose health risks due to high saturated fats. Consumer awareness of nutrition's role in preventing chronic diseases drives the need for healthier bakery products. This study focused on developing apple pomace emulsions (APE) as solid fat substitutes in biscuits. APE, rich in dietary fibers and antioxidants, can improve textural and nutritional properties of formulated products while promoting sustainability, as it is a by-product of the fruit processing industry. The effects of apple pomace concentration (12.5-20.0% w/w) and storage (4 oC, 7 days) of APE (olive oil:water 35:65 w/w) on their rheological properties and microstructure were studied. Dynamic rheology revealed the solid-like character of APE (elastic, G'> loss, G", moduli), with more elastic structures being observed at higher apple pomace concentrations. The size of oil droplets in APE decreased with increased apple pomace concentration. A selected APE (15% AP) was used as a margarine substitute in biscuits (50-100% substitution level). Biscuit hardness and resistance to fracture increased with increasing margarine substitution by APE, as indicated by Young's modulus (E) and fracture strength (σmax) values, estimated by the three-point bending test. Storage conditions (23, 43 and 75% RH for 15 days) significantly influence the biscuit flexural properties due to moisture adsorption or loss. In vitro lipid digestion showed a slower hydrolysis rate of triacylglycerols with higher levels of margarine substitution. Biscuits with 50% margarine substitution by APE showed similar textural attributes with control (biscuit made solely with 30% margarine) as assessed by both instrumental analysis and sensory evaluation. Overall, the structured APE dispersion system appeared to be a promising margarine substitute for reducing saturated fat and enhancing the nutritional profile of biscuits, while maintaining desirable product textural characteristics.

Acknowledgements: The authors would like to thank the Francophone University Agency (AUF), project DRECO-7863_SER-ECO_USVIIBI_DECHETJUS, 'Réutilisation totale des déchets de fruits et légumes issus de la production de jus: pigments et antioxydants pour les aliments fonctionnelles et biomatériaux pour la purification de l'eau'.

The use of starch and β-lactoglobulin composite hydrogels as frameworks for preserving c-phycocyanin 336

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ABSTRACT

C-Phycocyanin (C-PC), the natural blue dye and the major protein in Spirulina, has high potential in the food industry due to its vivid colour and bioactive properties. However, low stability limits C-PC application potential, requiring approaches to strengthen its stability. Our study aimed to preserve C-PC by its incorporation into hydrogels formed by combining starch and β-lactoglobulin (BLG) using high-pressure (HP) processing. Notably, thermal treatment resulted in the complete loss of colour derived from C-PC.

We performed a comprehensive characterization of the resulting HP gels by rheology measurements, texture profile analysis (TPA), small-angle X-ray scattering (SAXS), and scanning electron microscopy (SEM).

Different compositions of binary (BLG/C-PC) and ternary (starch/BLG/C-PC) systems were processed under high-pressure (HP) conditions reaching up to 4,500 bar. The C-PC pigment was effectively preserved by mixing BLG and starch with C-PC at pH 7, maintaining concentrations of 180, 5, and 10 mg/mL, respectively. The same concentrations of components were retained in the binary systems.

Rheological properties of the gels were determined using a rheometer with plane/plane geometry, and texture analysis was conducted through TPA. These findings enabled the assessment of food gel's properties, such as hardness, springiness, chewiness, and cohesiveness. The structural characteristics of the gels were determined by SAXS, offering insights into the interactions between C-PC, BLG, and starch after HP processing. Adding C-PC and starch formed solid gels with a larger mesh than the pure BLG gels. SEM scans of the gel surface revealed that all components influenced the overall morphology of gels. Adding starch notably influenced the gels' visual appearance and mechanical properties, even at low concentrations. Interestingly, the presence of C-PC substantially increases the gel's solubility in water.

Our investigation highlights HP treatment's superior effectiveness in preserving C-PC compared to high-temperature treatment, evidenced by the sustained colour integrity of the C-PC blue chromophore.

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Design structure of plant protein-based gels for sustainable food 339

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ABSTRACT

Plant protein products increasingly serve as "green" replacement for their animal counterpart; yet, design and prediction of the aggregation process in complex plant protein mixtures to make food products remains a grand challenge. Here, we make plant protein microparticles and use those as a model system to directly observe protein aggregation in real space. The microparticles are produced by emulsification and subsequent mild denaturation (by heating) causing aggregation of the proteins inside the emulsion droplets, subsequently leading to the formation of microparticles of size around 1 micron. The size distributions show we can make reasonably monodisperse, uniformity, stable protein microparticles. We follow the gelation of these protein microparticles upon lowering the pH, leading to destabilization of the suspension. The addition of GDL regulates the acidification rate and causes aggregation of the microparticle dispersions. When the pH of the dispersion is reduced to isoelectric point, the particles will be strongly attracted to form a rigid network. Because of their micrometer size, we can then follow the aggregation of these protein microparticles by optical microscopy in real space, providing insight into their gelation behavior for applications in plant-based foods.

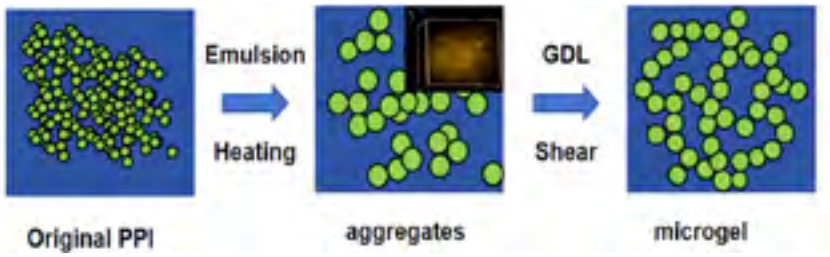

Figure 1. Plant protein microparticles as a model system to directly observe protein aggregation and gelation in real space

Acknowledgements: CSC: Chinese Scholarship Council

Folic acid-loaded Hydroxypropyl methylcellulose microparticles produced by electrospray: physicochemical characterisation and in vitro gastrointestinal assessment 340

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ABSTRACT

Folic acid (FA) is an essential micronutrient not synthesized by the human body, with a recommended daily intake (RDI) of 420 µg for adults. Food fortification with FA is challenging because FA is very sensitive to degradation leading to low bioaccessibility in the human gut. Additionally, despite being a hydrosoluble vitamin, it is difficult to solubilise in aqueous solutions at acidic and neutral pH, limiting its incorporation in some food products. Therefore, this work aimed to evaluate the effect of encapsulation FA in microstructures on its stability. Additionally the effect of pH formulation was evaluated on the capacity of producing microstructures using electrohydrodynamic processing (EHDP).

Therefore, for the production of the particles by electrospray two strategies were evaluated: a) using the electrospray FA solution at pH=12 and b) electrosprayed FA solution at pH=7. The produced particles were characterised in terms of size and morphology through scanning electron microscopy. Furthermore, in vitro gastrointestinal digestions were conducted to assess the bioaccessibility of FA. Cell metabolic activity assays were also performed to examine the potential cytotoxicity of the encapsulated FA.

Obtained results demonstrate the efficiency of the electrospray process in producing FA-loaded HPMC particles, with an average size of ≈ 1 µm, featuring a spherical shape and a smooth surface. Thermogravimetric analysis revealed that the incorporation of FA into HPMC particles contributed to the thermal stabilisation of FA and improved bioaccessibility, increasing it from 29% for free FA to 80% for FA-loaded HPMC particles. Additionally, results showed that FA-loaded HPMC particles have no adverse effects on cell metabolic activity.

This study highlights the potential of using electrospray for the production of FA-loaded HPMC particles and a promising approach to improve FA bioaccessibility. This can contribute to the development of fortified food products with enhanced nutritional value.

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Stability of spreadable processed whey cheese with guar gum addition, as affected by storage time and temperature 342

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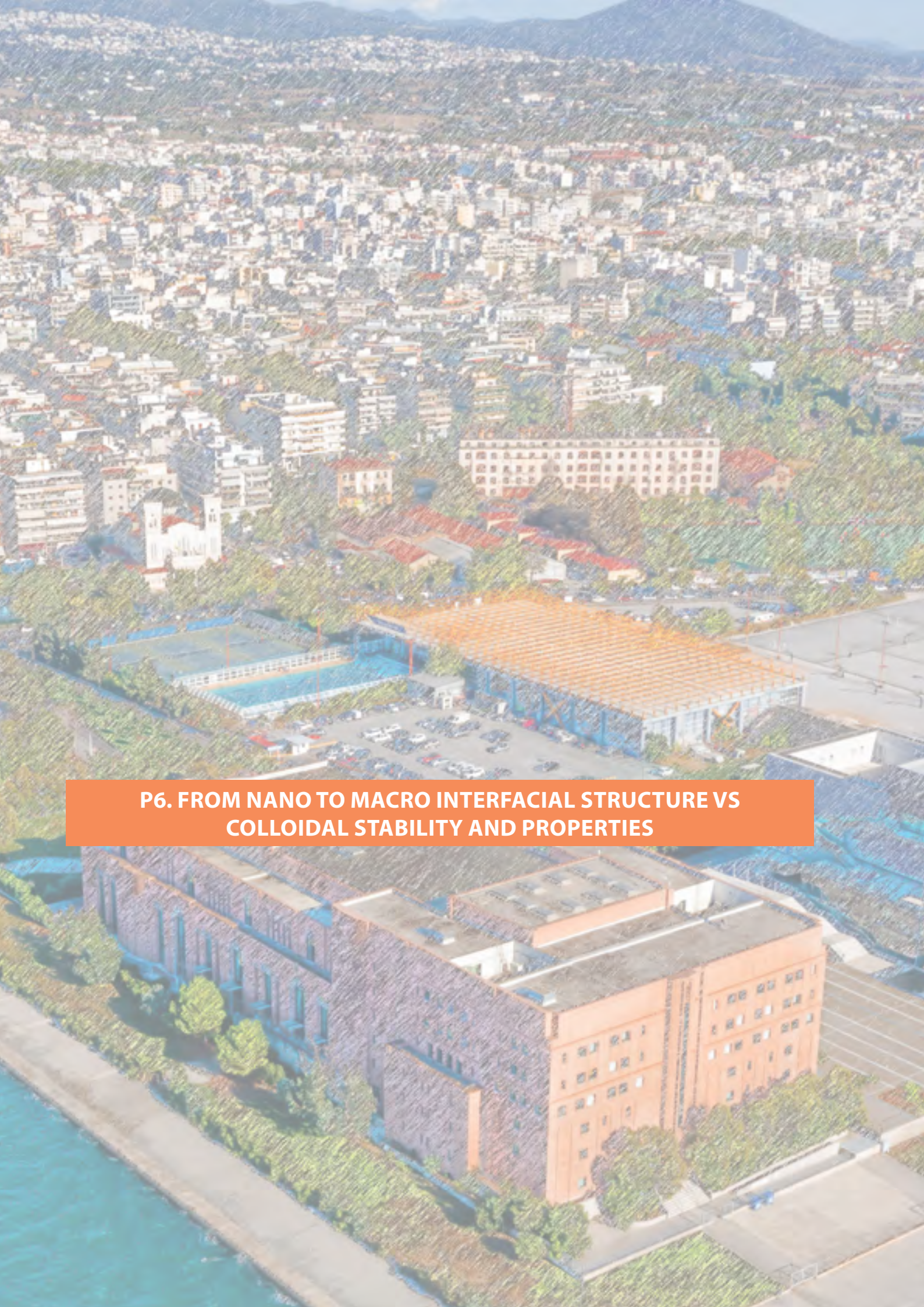
ABSTRACT

The aim of this work was to study the influence of storage time and temperature on the physicochemical and rheological properties of a novel, spreadable processed whey cheese (PWC), prepared with whey cheese as the sole cheese base and guar gum as a stabilizer. The effect of storage time (up to 24 weeks) and storage temperature (4 and 25oC) on the properties of PWC was evaluated. PWC samples showed no syneresis and fat separation throughout their 24 and 12 week storage at 4 and 25°C, respectively. Additionally, there was no appreciable change in their chemical composition and color. The distribution of fat globule size showed that the emulsification was relatively stable at the beginning of storage, while during storage at both temperatures a more intense polydispersity was observed. PWC samples presented an increasing free oil formation during storage, which was shown to be more pronounced at 25°C ($p<0.05$), which indicated that the partial coalescence of fat globules via the mechanism of interfacial rupture by fat crystals was not the main mechanism of fat globule destabilization. Results of lubricated squeezing flow and penetration tests revealed that from the 4th week of storage onwards, samples had reduced viscous character and decreased consistency and adhesiveness. PWC samples also presented lower rigidity and pseudoplastic character. Microbiological determinations showed that all samples were safe for consumption following storage at 4oC for 24 weeks, but also at 25oC for 12 weeks. The preparation of spreadable processed whey cheeses with the addition of guar gum resulted in stable samples with an increased shelf life. The innovative products under development are an alternative way of exploiting milk whey, the main by-product of cheese making, for the industrial production of new products with high nutritional value, as well as added value.



P6. FROM NANO TO MACRO INTERFACIAL STRUCTURE VS COLLOIDAL STABILITY AND PROPERTIES

Air-water interface properties and foam stabilization by mildly extracted lentil protein 3

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ABSTRACT

Lentil proteins have shown potential as substitutes for animal proteins in foam-based food products, although the mechanisms by which the proteins stabilize the air-water interface are largely unexplored. Here, we systematically studied the air-water interfacial behavior (including adsorption kinetics, and interfacial dilatational and shear rheology), interfacial structures and foaming properties of mildly extracted lentil protein isolate (LPI). We compared these properties of LPI with two animal-based proteins commonly used in food industry, i.e., dairy-derived whey protein isolate (WPI) and egg-derived egg white protein isolate (EPI). The mildly extracted LPI had high protein content (85.2%), high protein solubility (91%) and high nativity, with a globulin-to-albumin ratio of 81:19. LPI adsorbed fast at the air-water interface, showing a foam overrun of 285% that is comparable with WPI and EPI. Although LPI formed interfaces with lower stiffness than EPI, it showed comparable foam half-life time (115 min) with EPI, due to the higher thickness of the interface formed by LPI, which is dominated by lentil globular protein particles with a size around 11 nm. The lentil globular proteins appear to have weaker in-plane interactions than smaller WPI molecules at the air-water interface, resulting in a pronouncedly lower interfacial stiffness and foam half-life time of LPI compared to WPI (295 min). However, the LPI-formed interface is more stretchable than the WPI-formed interface and shows less disruption in both large dilatational and shear deformations. Thus, LPI might have comparable or better performance than WPI in stabilizing foam under processing conditions. Overall, lentil proteins have good foaming properties and could be applied as an animal-based protein replacer in producing foam-based food products.

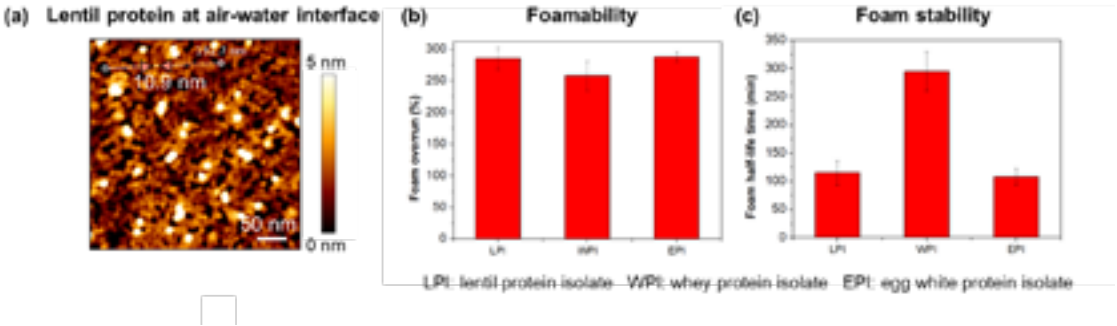

Figure 1. (a) AFM image of lentil protein isolate (LPI)-prepared Langmuir-Blodgett film. Foam overrun (b) and foam half-life time of LPI, whey protein isolate (WPI) and egg white protein isolate (EPI) at 0.1% (w/w) protein at pH7.

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Characterisation and interfacial properties of foams stabilised by mung bean proteins and pectin 39

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ABSTRACT

Mung beans are a rich source of protein with good foaming properties. However, their application in foods is limited due to its low solubility under acidic conditions. Previous studies have reported that the solubility of proteins can be improved by mixing with polysaccharides. Therefore, we aimed to investigate the interfacial properties of mixtures of low methoxyl pectin (LMP) and mung bean protein isolate (MBPI). The electrostatic interactions between MBPI and LMP were characterised at different pH and ratios, to construct the state diagram (Fig. 1a). The pH dependent complex formation was investigated via turbidity measurement. The stability and foamability of MBPI and mixtures were explored. Our results revealed that, the introduction of LMP to MBPI solution could improve its functionality near the isoelectric point. The maximum turbidity of the mixture was lower compared to native MBPI, indicating the addition of LMP could reduce the self-aggregation of MBPI. To understand the interfacial properties of the mixture, a 1:1 ratio of MBPI/LMP solution under pH4 was subjected to large amplitude oscillatory dilatation and shear rheology. The surface microstructure was analysed by imaging with atomic force microscopy. We used Lissajous plots to characterise the non-linear responses and observed that both native MBPI and the mixture stabilised the interface by forming a viscoelastic solid film. The mixtures showed higher surface dilatational moduli, suggesting the interfacial film became stiffer. For the shear behaviour, the presence of LMP resulted in the formation of a stiffer interface in the linear regime, however, a less stiff and more viscous interface was observed at large deformation. The foam stability of the mixtures was improved because of the higher stiffness of the interfaces and higher viscosity of the continuous phase. This study provides insight into mung bean protein-pectin interaction and their interfacial behaviour which can be linked to foaming properties.

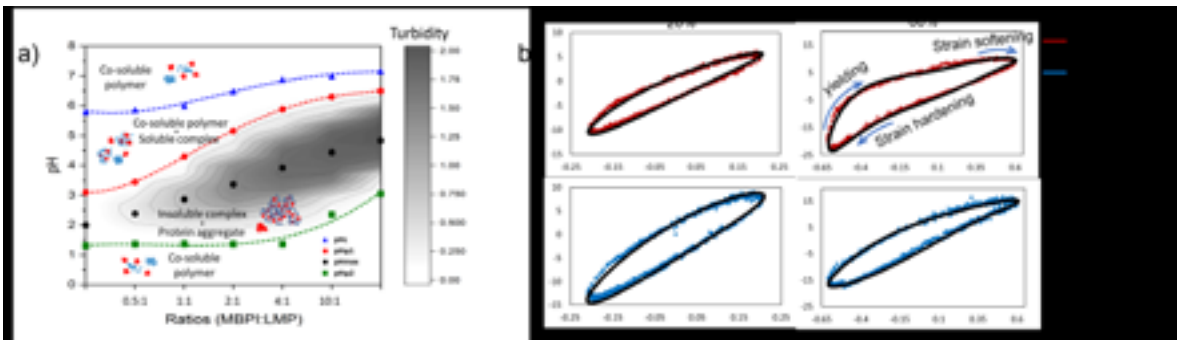

Figure 1. (a) State diagram of MBPI/LMP mixture as derived from turbidity curve, and (b) Lissajous plots of surface pressure as a function of the applied dilatational deformation.

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The dual functionality of di-acylglycerides in lipid systems 56

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ABSTRACT

Oleogels, semi-solid gels made of vegetable oil and structuring agent, were proposed as healthier alternatives to conventional fats due to their high unsaturated content, providing an improved nutritional profile while maintaining similar sensory attributes as fats. Incorporation of water phase into oleogels, termed emulsion gels, can improve these characteristics even further. Extensive research was published on gelation of oil using mono-acylglycerides and tri-acylglycerides but little information can be found on the oil structuring performance of di-acylglycerides (DAGs).

The current research aims to investigate the dual functionality of DAGs as oil structuring agent and as interfacial stabilizer of water-in-oleogel systems. For that, di-stearin (DS) oleogels and water-in-oleogel systems were prepared using various DS concentrations and water/oleogel ratios. DS formed stable oleogels with a minimum concentration of 10 %wt. and stable emulsion gels with a maximum water content of 30 %wt. DS-based emulsion gels with 30 %wt. water showed a significantly higher gel strength compared with oleogels with the same DS concentration. Interestingly, oleogels demonstrated behavior similar to ideally elastic materials characterized by a zero slope in a frequency sweep test, while emulsion gels exhibited a frequency dependent behavior with a slightly positive slope. Both oleogels and the corresponding emulsion gels exhibited typical sol-gel transitions characterized by a cross-over between the storage and loss modulus and thermo-reversible behavior. DS crystallization in oil revealed the formation of large spherulite crystals, whereas water addition and homogenization reduced the crystal size. Moreover, aggregated crystals were found around the wtare/oil interface, implying on the involvement of DS crystals in the interfacial stabilization of the biphasic system. Overall, saturated DAGs can be used as oil structuring agent as well as surface active agent in emulsion gel systems. Such ability can be exploited while developing new food products based on biphasic systems like Margarine and Mayonnaise.

Tuning interfacial properties of protein-phospholipid stabilised oil-water interfaces by changing the phospholipid headgroup or fatty acid chain 106

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ABSTRACT

In the food industry, oil-water emulsions often contain a mixture of phospholipids (PL) and proteins such as beta-lactoglobulin (β-LG). Two phenomena were previously shown in systems where β-LG and PL are present simultaneously: (1) The replacement of β-LG by PL, leading to a weak PL-dominated interface, thus a low process stability; (2) Interactions between β-LG and PL, leading to an increased interfacial viscoelasticity. Recently, we have shown that PL's molecular structure (head group, fatty acid chain) correlates with these phenomena. We hypothesize, the fatty acid chain determines whether interactions between PL and β-LG occur, while the head group decides the strength of interactions. It is still not clear in which way environmental conditions impact these interactions. Furthermore, the order of emulsifier addition (first PL in the system, then protein addition or the other way around) most likely is relevant for the final interfacial properties. Finally, the emulsion undergoes temperature cycles during processing, which will affect interfacial properties due to the melting/crystallisation of the emulsifier. This temperature impact has often been neglected in the literature.

The present study aimed to analyse the effect of the order of emulsifier addition, temperature cycles and pH on PL-ß-LG interactions. The interfacial properties were investigated within and outside the linear viscoelastic regime via dilatational and interfacial shear rheological measurements.

The protein adsorption and/or the protein network formation is partly interfered when introducing the PL to the system first. As a consequence, the deformation behaviour is dominated by the phospholipid. Temperature cycles determined the physical state of the phospholipid, but when introducing the ß-LG to the system first, the impact of the cooling on the final interfacial properties is not that severe. The interfacial stability of PL-ß-LG stabilised oil-water interfaces increased with decreasing pH due to the change in protein conformation which favors stronger PL-ß-LG interactions.

Relation between critical coalescence pressure of oil droplets and antifoam activity in foamed soy protein emulsions 109

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ABSTRACT

Oil droplets can effectively reduce foam formation and stability by antifoam activity1. Knowledge on antifoam activity in (plant) protein foams is limited2. The aim of this research is therefore to relate food specific parameters, such as protein properties, interfacial microstructure and emulsion mesostructure, to the degree and mechanisms of antifoam activity in model plant protein stabilized foams.

Soy protein stabilized sunflower oil-in-water emulsions with a mean droplet size of 4 ± 3.7 µm were produced using a lab scale rotor-stator shear mixer. Subsequently, dispersions of soy protein isolate were foamed in the presence and absence of emulsion droplets using a standardized stirring test3. Furthermore, droplet resistance against coalescence was probed using a centrifugal forced emulsion destabilization method4.

Addition of as little as 0.2 vol% of oil droplets to a 0.5 wt% protein dispersion prior to foaming resulted in a drastic foamability reduction of more than 80%. Milder antifoam activities with foamability reductions of around 40% or less were observed at protein contents between 0.7 and 1 wt% protein and 1 vol% oil droplets. Similar antifoaming trends were observed for dispersions differing in average protein particle size or prepared from protein isolates obtained with different procedures. A strong increase in oil droplet resistance against coalescence of emulsions produced with >0.5 wt% soy protein correlated well with the observed transition from drastic to milder antifoam activity at higher protein contents in the stirring test.

Results indicate a strong influence of droplet coalescence resistance and a comparatively limited effect of the evaluated protein properties on antifoam activity in protein dispersions. Thus, novel insight was gained into the relation between colloidal aspects of food systems and antifoam activity. Future experiments will assess the role of foaming methodology, oil droplet size and system conditions such as pH and temperature.

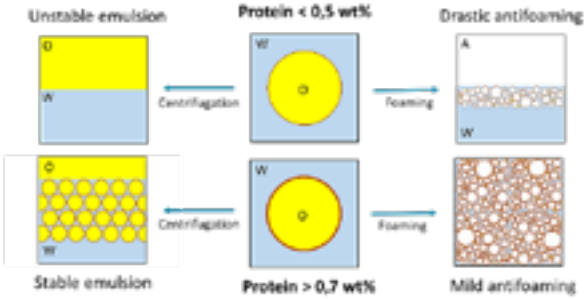

Figure 1. Graphical Abstract

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De-emulsification of a waste emulsion formed during processing of fish wastes 153

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ABSTRACT

Valorization of seafood wastes into fish feed which is carried out through enzymatic hydrolysis could itself result in generation of a waste emulsion. Disposal of the waste emulsion into the environment not only endangers aquatic life but also leads to loss of food components. The aim of this study was to break the emulsion to recover food compounds. A protocol consisting of various physical and chemical treatments was developed to displace the surface-active agents from the interface. The interface consisted of peptides and phospholipids. The peptides were fractionated based on their molecular weights and the types of phospholipids were identified. The interfacial properties of different fractions of the interface were examined to select the most surface-active agents. The interfacial activities were then monitored in the presence of site-specific enzymes capable of destructing the structures of the surface-active agents. The enzymes with the highest ability to diminish the interfacial activities were applied to the bulk emulsion.

Acknowledgements: This research was funded by Norwegian University of Science and Technology (NTNU).

Investigating the effect of pH, heating and NaCl on the stability of nanoparticles formed from ethanol pre-treated whey proteins 183

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ABSTRACT

Whey protein nanoparticles have attracted considerable attention as functional ingredients. This study investigates the potential of whey proteins denatured with ethanol to form ethanol-free nanoparticles. The stability of the resultant ethanol-free nanoparticles was examined under various conditions including heat treatment, pH modification, and addition of salt (NaCl).

Nanoparticles were formed at varying ethanol concentrations (10–70% w/w) and low protein concentration (1.0–2.0% w/w) by regulating pH and ionic strength. Subsequently, ethanol was removed through a two-step process involving rotary evaporation and freeze drying. The particles were characterized in terms of their morphology (size and shape) using confocal laser scanning microscopy, laser diffraction analysis, and scanning electron microscopy.

The findings of this study demonstrate that the removal of ethanol resulted in the formation of spherical nanoparticles with diameters ranging from 100 to 200 nm. Changes in pH had a substantial impact on the stability of these particles, with aggregation observed near the protein's isoelectric point, while stability was maintained at other pH values. Finally, the addition of high concentrations of NaCl induced extended aggregation; however, these particles remain remarkably stable when subjected to heating treatment.

The results indicate the successful formation of stable whey protein nanoparticles after ethanol removal. This development has potential uses in a range of food applications.

Relationship between dry heat induced protein changes and heat stability of recombined filled evaporated milk emulsions: effects of relative humidity on low heat skim milk powder 205

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ABSTRACT

Skim milk powder (SMP) is widely produced and used as an ingredient in various food applications, such as yoghurt, fermented milk products, and recombined filled evaporated milk (RFEM). However, RFEM may suffer from heat-induced coagulation during manufacturing. Moderate Maillard reaction (MR) between milk proteins and lactose by dry heat incubation has been used for improving the heat stability of RFEM. However, the extent of the glycation reaction and its relationship with the functional properties of SMP remain unveiled. Understanding the heat-induced milk protein changes is of high value for the dairy industry in improvement of the storage stability and quality control. This study applied dry heat incubation (at 60 °C) to SMP at various relative humidity conditions (i.e., 0, 29, 50, 74, 95% RH) to improve the heat stability of RFEM. The glycation of the whey proteins and caseins with lactose was confirmed by free amino group determination and SDS-PAGE. The color development results indicated that increasing the RH promoted the development of MR as well as protein cross-linking, especially with a longer incubation time up to 16h and 24h. Properly modified proteins via dry heat treatment at each RH (of 0, 29, 50, 74, or 95%) could greatly improve the heat stability of RFEM. However, overheating up to 24h also induced severe coagulation. Different from the conclusion in previous studies, our results indicated that there was no direct relation between heat stability and the formation of protein carbonyl and sulfhydryl group. Instead, the concentration of glycated proteins seemed to be the most important characteristic.

Understanding Structural Changes in Phycocyanin-Pectin Complexes: Impact of Esterification and pH 266

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ABSTRACT

Phycocyanin is a blue protein derived from the cyanobacteria Arthrospira platensis commonly referred to as "Spirulina". The protein exhibits severe color instabilities at acidic pHs due to decreased electrostatic repulsion as well as protein unfolding. Complexation with pectin was introduced to increase the color and colloidal stability by reducing the protein unfolding and enhancing the inter molecular electrostatic repulsion. So far, the structural changes of the complexes, which determine the precipitation velocity, have not been investigated in detail. This study focused on the arrangement of complexes prepared at pH 3-5 and the corresponding color changes. Citrus pectin with changing degrees of esterification (DE; 9, 22, 35, 45, 60) was applied. Color and transmittance of the samples was evaluated via photometric measurements. The complex structures and sizes were determined with an optical microscope, a confocal laser scanning microscope, high pressure size exclusion chromatography, dynamic light scattering and static light scattering. Rheological analyses were performed to determine the voluminosity, which is a measure of the complex's density. The results showed that highly esterified (DE 60) pectin formed loose structures (d3.2 1.33 ± 0.24 µm) at pH 4, which became denser and smaller (d3.2 0.21 ± 0.00 µm) upon decreasing the pH to 3 (Figure 1). Low esterified pectin (DE 9) formed dense aggregates independent of the pH. However, upon decreasing the pH towards 3 aggregates clustered and increased in size (57.28 ± 10.20 µm) which led to immediate precipitation.

Overall, the increased steric hindrance introduced by pectin DE 60 could benefit the colloidal stability of the complexes. Not only do the results show the importance of selecting the right type of pectin for the stabilization of phycocyanin in applications such as beverages. Moreover, the results show how protein-pectin complexes can be tailored in terms of size and density to control precipitation processes.

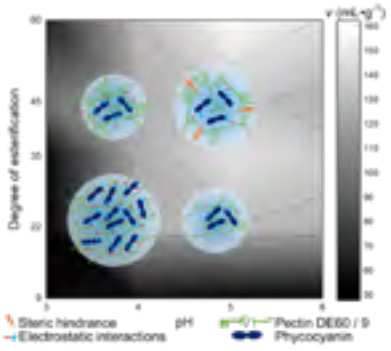

Figure 1. Voluminosity (v mL•g^{-1}) of phycocyanin-pectin complexes as a function of pH and degree of esterification and a schematic representation of the complexes.

Acknowledgements: This research was supported by GNT Europa GmbH.

Concentration-Dependent Effects of Sunflower Oleosomes on an Air-Water Interface 341

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ABSTRACT

The behaviour of fresh and heat-treated oleosomes at an air-water interface was measured. The recovered crude oil bodies (COB) were suspended at pH 8.5 and the suspension centrifuged to yield a washed oleosome cream called washed oil bodies (WOB). WOB samples were dispersed in ultra-pure water (Rinsed-washed oil bodies – RWOB) and heat-treated (HT) at 75 °C/ 0.5 min, 75 °C/ 5 min, 95 °C/6 min or 63 °C/30 min, or kept as a non-heat-treated (Fresh). Protein concentration, and lipase activity of suspensions reduced with heating, the degree of reduction increasing with increasing thermal treatment. These changes seem to be associated with the loss of extraneous proteins after heating. After heat treatment the mean particle size remained at just over 1 µm, with only the higher temperature and time conditions (95°C/6min or 63°C/30min) resulting in the emergence of a population of larger particles that are at least 3-8 µm.

The behaviour of oleosome (Fresh and HT) preparations over a range of concentrations at an air-water interface was established by measuring their impact on surface tension. All oleosome preparations caused a reduction in the surface tension (ST); this reduction was more rapid and extensive with fresh RWOB. This observation, along the parallel measurements of the impact of the serum phase of these preparations, suggest that the presence of extraneous proteins cause a reduction in ST. Further studies using HT-RWOB (75 °C/5 min) revealed that there was a concentration dependent decrease in ST between 0.005% and 0.2% (w/v) with only a slight increase at 0.8% and 1.0%. Particle size measurement and micrographs of emulsions before and after ST measurement indicate significant breakage and coalescence of oleosomes. The paper explores the impact of these changes in the oleosome material on the surface tension and suggests possible explanations.

Keywords: Sunflower, Oleosome, Oil Body, Interfacial Tension, Surface Tension, Colloidal Stability

Acknowledgements: This research was funded by the UKRI BBSRC DTP-programme in collaboration with Unilever

P7. SURFACTANTS, LIPIDS, MACROMOLECULES, PARTICLES ADSORPTION, INTERACTIONS AND SELF-ASSEMBLY

Escin: a natural foam performance booster and interfacial plasticizer – studied in WPI-escin mixtures using interfacial rheology and visualization approaches 5

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ABSTRACT

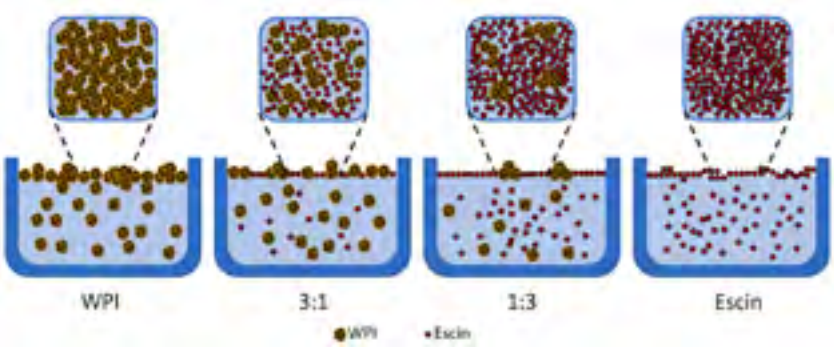
Saponins are naturally occurring components in plants with promising interface and foam-stabilizing properties. In this work, we focus on the saponin called escin, which is studied in a mixture with whey protein isolate (WPI), as understanding the role of escin in multicomponent systems is key for its implementation in foods.

WPI-escin systems were studied for their interface and foaming properties. A range of ratios from 7:1 to 1:3 (WPI:escin) was evaluated using interfacial shear and dilatational rheology. In shear rheology, we demonstrate a plasticizing effect of escin on a WPI-interface at a 3:1 ratio. At higher escin concentrations, the escin started to dominate the overall rheological behavior of the interface. An exciting element is the superposition of self-similar behavior with time-concentration of the different WPI-escin ratios in frequency sweeps. The superposition was well fit using a multi-mode Maxwell model. In addition, we observe a superposition of the overshoot in loss moduli in amplitude sweeps, known as the Payne effect, which was well-described by a Vogel-Fulcher-Tamman type fit.

The overall rheological behavior suggests heterogeneous structures, which were confirmed using AFM on Langmuir-Blodgett films. Here, we observe 2D-phase separation, where whey proteins started forming clusters surrounded by escin molecules.

In dilatational rheology, we observed an immense increase in interfacial stiffness when only replacing 12.5% of the WPI with escin. An even stiffer interface is observed by replacing more WPI with escin. This positively affects foaming properties, as 1) the air bubble sizes reduced >4 times, 2) the foamability increased up to 30%, and 3) stability doubled compared to pure WPI systems.

In conclusion, we show a protein-to-escin ratio effect on the air-water interface and a high boost in foaming properties when including escin. Escin has a high potential as a foam-boosting ingredient in future food systems.



Application of multilayer emulsions stabilized with carob protein hydrolysates and pectin for the microencapsulation of linseed oil by spray drying 8

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ABSTRACT

Regular consumption of oils rich in omega-3, as linseed oil (LO), brings health benefits. However, these oils are susceptible to oxidation during processing. Microencapsulation associated with protein hydrolysis and multilayer emulsions can enhance oil stability. This study aimed to evaluate the application of multilayer emulsions stabilized with protein hydrolysates and pectin in the microencapsulation of LO through spray drying. Carob protein concentrate (CPC) was hydrolyzed to a degree of hydrolysis of 2% (CPH). Two multilayer emulsions (CPCME and CPHME) (5% w/w of CPC or CPH; 10% w/w of LO; 1% w/w of pectin; and 29% w/w of maltodextrin) and two single-layer emulsions (CPCSE and CPHSE) (5% w/w of CPC or CPH; 10% w/w of LO; and 30% w/w of maltodextrin) were obtained. All emulsions were characterized regarding rheological behavior, mean oil droplet size (D3,2), and stability (backscattering profile), followed by spray drying. Microparticles were evaluated for microencapsulation efficiency (EE) and scanning electron microscopy (SEM). The emulsions exhibited a Newtonian behavior, with viscosity from 0.033±0.003 to 0.063±0.001 Pa·s, in which CPH and the multilayer promoted an increase on it. D3,2 varied from 3.89±0.02 to 5.37±0.05 µm, with CPH and the multilayer capable of reducing it. The polydispersity index ranged from 2.52±0.04 to 4.87±0.73, indicating that the emulsions were well polydisperse, with higher values for the multilayer samples. Multilayer emulsions were more stable than single-layer emulsions, with the latter showing phase separation after 1 hour. CPH also influenced stability, showing a slight reduction. For the microparticle, the EE ranged from 56.49±3.70 to 72.47±1.07%. CPH had a positive effect on EE, increasing ~12% compared to particles containing CPC. All microparticles exhibited similar microstructures by SEM analysis, having a continuous wall with few grooves and/or ruptures. Thus, CPH as stabilizing agent in multilayer emulsions can be an outstanding alternative for the microencapsulation of LO.

Acknowledgements: This study was supported by São Paulo Research Foundation (FAPESP) (grant numbers: 2021/06606-4 and 2019/27354), Coordination for the Improvement of Higher Education Personnel (CAPES) and National Council for Scientific and Technological Development (CNPq).

Green amphiphilic xanthan derivative: a promising multifunctional ingredient in the stabilization of oil-in-water emulsions 54

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ABSTRACT

Among others, amphiphilic modified polysaccharides represent one of the green solutions to replace conventional surfactants [1], the latter being controversial because of their harmful toxicological and environmental impacts [2]. The enthusiasm for the exploitation of polysaccharides is explained by several advantages including availability, biodegradability, non-toxicity and low cost [3]; another advantage is their potential for chemical modification which allows them to acquire outstanding physicochemical properties. In the present project, xanthan polysaccharide was hydrophobically modified following the principles of green chemistry in order to enhance its interfacial properties in addition to its remarkable inherent thickening and viscosifying capacities.

A series of xanthan derivatives was first prepared through green esterification using alkenyl succinic anhydrides varying from alkyl chain length as grafting agents [4]; then corresponding physicochemical characterizations were analyzed in aqueous solution as well as the emulsification potential was investigated by preparing oil-in-water emulsions without adding any conventional surfactant.

The rheological behavior study proves that amphiphilic xanthan (AX) conserve the well-known viscoelastic and flow behavior of a pristine xanthan (PX), but highlights the presence of intermolecular interactions slowing down the chain dynamic in the macromolecular network [5]. Finally, results demonstrate that, comparing to PX known for its poor interfacial properties as a non-absorbing polymer [6], AX own a high emulsifying potential capable of stabilizing Oil-in-Water emulsions [7] as illustrated on Figure 1.

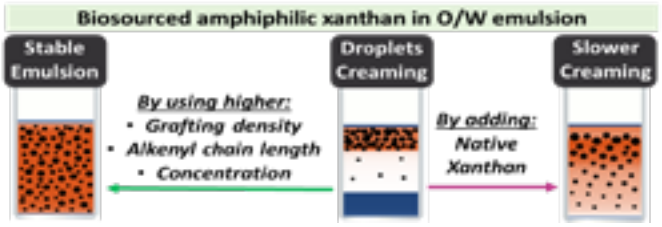

Figure 1. Amphiphilic xanthan stabilizing Oil-in-Water emulsions

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Interfacial adsorption behaviour of phosphatidylcholine-depleted (PC-depleted) lecithin as low-HLB emulsifier in W1/O/W2 double emulsions 57

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ABSTRACT

Water-in-oil-in-water (W1/O/W2) double emulsions (DEs) offer the potential to develop low-fat and functional foods. However, the limited range of food-grade hydrophobic emulsifiers hinders their application in the food industry. PC-depleted lecithin owns a lower phosphatidylcholine/ phosphatidylethanolamine ratio, favoring the formation of water-in-oil (W/O) emulsions, and thus can be applied in DEs to replace PGPR. However, its adsorption and stabilization mechanisms in DEs are still unclear.

In this work, the effect of PC-depleted lecithin on the formation and stability of W/O and W1/O/W2 emulsions was studied under different formulation and processing conditions. The emulsions were characterized by morphology, droplet size, and entrapped water yield. Subsequently, the interfacial properties (interfacial tension and viscoelasticity) of PC-depleted lecithin were investigated via a drop shape tensiometer, aiming to further understand its emulsifying and stabilizing mechanism in DEs.

The formation of PC-depleted lecithin-based W/O emulsions was found to be highly dependent on the oil type, homogenization method and W1/O ratio, independent of osmotic agent and lecithin concentration. Furthermore, the formation of DEs was inhibited by an increased salt concentration. The storage stability of DEs was more influenced by the type of oil and hydrophilic emulsifiers, and less affected by the 1st homogenization method, W1/O ratio and lecithin concentration. From the perspective of interfacial adsorption, PC-depleted lecithin showed a much slower adsorption at the oil-water interface in long-chain triglyceride oil than in medium-chain triglyceride oil. The presence of more salt led to a lower interfacial tension due to the electrostatic screening effect. In terms of the influence of protein addition, sodium caseinate lowered the interfacial tension sharply and also decreased the viscoelasticity modulus, whereas whey protein isolate showed a minor effect on both interfacial tension and viscoelasticity. Overall, it was confirmed that PC-depleted lecithin can be applied to produce stable DEs by adjusting the formulation.

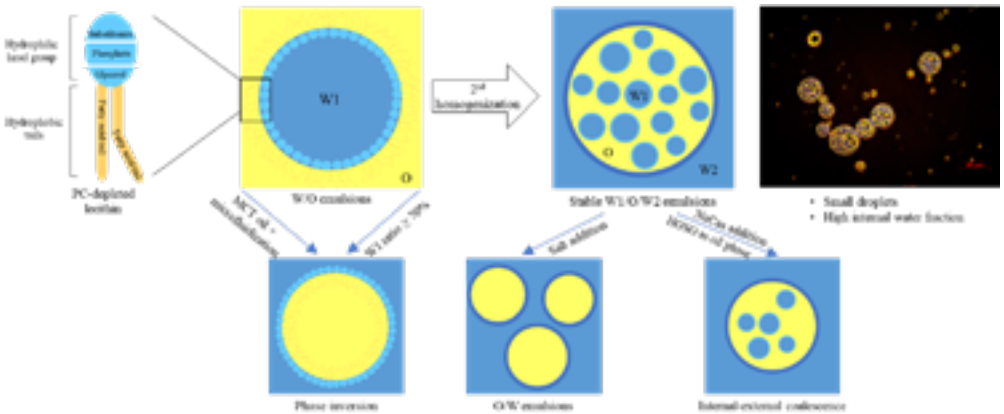

Figure 1. The preparation of W1/O/W2 double emulsions with PC-depleted lecithin as low-HLB emulsifier and related instability mechanisms caused by different conditions.

Acknowledgements: We acknowledge the Chinese Scholarship Council (CSC) for funding and Cargill for providing the lecithin.

Pickering emulsions emulsified with protein-based Janus particles for food applications 73

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ABSTRACT

Janus particles are often seen as Pickering emulsifiers and several methods have been developed to fabricate Janus particles. However, their potential applications in the food industry are still hindered because of food-approved materials regulation. We propose a novel method to produce protein-based Janus particles using electrohydrodynamic co-jetting process with two food-approved proteins, hydrophobic zein and hydrophilic sodium caseinate. Pickering emulsions were produced with these Janus particles and larvae oil. Two emulsifying methods were employed to investigate the influence on the physical stability of oil droplets. These Janus particles were characterized by scanning electron microscopy and zeta size to confirm their morphological properties. Opitcal microscope and mastersizer were employed for characterizing properties of emulsions. The particle size was 600 nm for particles obtained in the supernatant after centrifugation whereas it was up to 8 µm for particles in a suspension of the precipitate. Two compartments of Janus particles were also confirmed with SEM images of suspensions of precipitate. Emulsification of Janus particles and sago palm weevil (Rhynchophorus ferrugineus) larvae oil were conducted by using a microfluidizer (9 kpsi and 3 passes) or ultrasonicator (15W at 2 intervals of 30s on and 60s off), resulting in stable oil-in-water Pickering emulsions with 2wt% oil and 0.05wt% protein concentration. Pickering emulsions stabilized with Janus particles (zein : sodium caseinate ratio of 4:1) exhibited stability for 4 days, with unchanged oil droplet size of 0.4 µm and 0.6 µm for microfluidizer and ultrasonicator methods, respectively. In conclusion, the electrohydrodynamic co-jetting process showed promise for efficient fabrication of food-approved Janus particles and Pickering emulsions from both emulsifying methods show physical stability during 4 storage days.

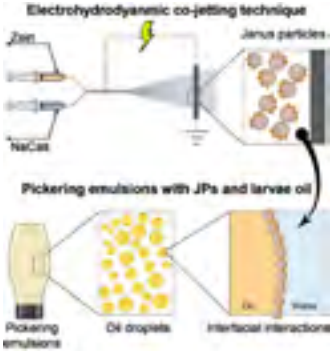

Figure 1. Pickering emulsions stabilized by protein-based Janus particles from EHD technique.

Acknowledgements: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 956248.

Molecular Structure and Interactions of Whey Protein Aggregates in Dispersion and Effects of Heat Treatment 135

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ABSTRACT

Protein aggregates are promising functional ingredients for application in food systems. Thermal induced whey protein aggregates have shown altered viscosity behavior in dispersion compared to native proteins. However, the molecular mechanisms responsible for this behavior are unexplored. Thus, interactions with components in food matrices such as minerals are of interest to investigate as well as potential structural changes during heat treatment. We have established phase diagrams of whey protein aggregate dispersions after heat treatment as function of protein, sodium, and calcium concentration. Molecular changes after heat treatment of varying aggregate dispersion formulations have been elucidated by small-angle X-ray scattering and electron microscopy. Scanning electron microscopy images showed spherical aggregates of uniform size in correspondence with particle size results by dynamic light scattering. Large variations in gelation behavior were observed in the low concentration range of both protein and minerals. Furthermore, heat treatments at varying temperatures between 80-145 °C and varying time between 2 min to 48 h have been investigated. The temperature during heat treatment had a major effect on the structural changes of the aggregate dispersions whereas the time of heat treatment seemed to be less important for inducing structural changes.

Acknowledgements: The project is funded by Arla Foods and University of Copenhagen.

The competition between endogenous phospholipids and proteins from pea protein ingredients rules their interfacial properties 155

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ABSTRACT

Sustainable incentives foster the use of plant-based ingredients as emulsifiers, but their functionality, for instance in terms of solubility, is far from optimal. The underlying reasons encompass a lack of characterization of the physicochemical properties of such ingredients. Thus, we comprehensively analyzed the composition of pea and lupin protein isolates and concentrates and highlighted a large part of non-proteinaceous compounds, notably lipids, constituting 3.8 to 11.7 wt.% (d.m.) of the powders. Over half of these lipids were phospholipids, which may have a pivotal impact regarding interfacial properties. A high-pressure homogenization (HPH) treatment was applied to aqueous suspensions of the ingredients. It broke down undispersed powder grains, enhanced protein solubility and released endogenous submicron lipid structures [1]. The interplay between these endogenous lipids and proteins was investigated regarding emulsifying and interfacial properties. Oil-in-water emulsions (10 wt.% oil) were prepared using HPH to reach droplet diameters around 2.5 µm. Protein surface load, composition measurements, and microscopic investigations suggested the formation of different interfacial films and an inner competition between proteins and phospholipids for interfacial adsorption. Therefore, we conducted complementary dilatational interfacial rheology analyses, using our commercial pea isolate on the one hand, and purified pea proteins and lipids on the other hand. Oscillatory deformations of the oil-water interface were analyzed by Lissajous plots (Figure 1), which substantiated the interactions between proteins and lipids by deciphering their respective contributions. The formation of mixed interfacial films according to the protein-to-lipid ratio was demonstrated, with notably a prevalent influence of pea lipids on the rheological signature of the mixed films. Atomic force microscopy confirmed the formation of mixed interfacial films where lipid domains coexisted with protein aggregates. These insights are key to understand the interactions between plant proteins and endogenous lipids in emulsions, and thereby to facilitate food products' rational formulation with such complex ingredients.

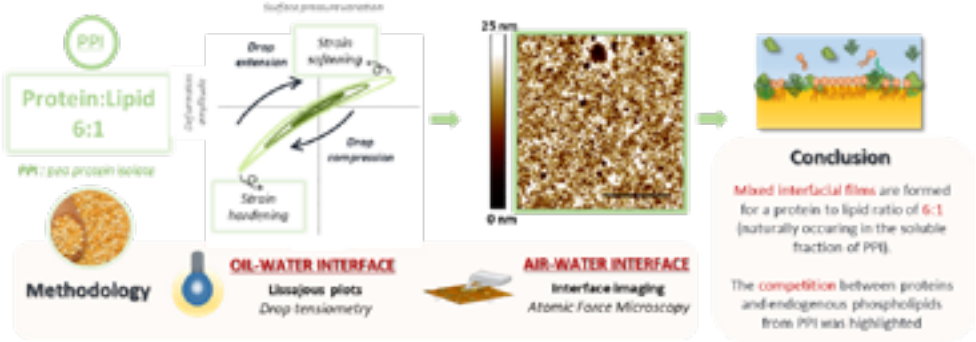

Figure 1. Approach deployed to understand the interfacial properties of commercial pea protein isolates.

Reference: [1] Keuleyan, E. *et al.* (2023), *Food Hydrocolloids*, 141. doi: 10.1016/j.foodhyd.2023.108671.

Acknowledgements: The financial support of EK's PhD grant, and of CBC's Connect Talent "VESTA" grant by Région Pays de la Loire and Nantes Métropole is gratefully acknowledged.

Oleosomes (Lipid Droplets) as carriers of hydrophobic therapeutics into model cell membranes (liposomes) 156

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ABSTRACT

Improving efficient therapeutic/drug carriers is challenging due to concerns about the biodegradability of engineered/synthetic carriers. Oleosomes (Lipid droplets) which are natural droplets in cells with the intrinsic property to store and transport hydrophobic molecules might offer a solution. Oleosomes can be extracted from seeds and we were able to load them with hydrophobic therapeutics (curcumin). After the successful encapsulation of curcumin, we investigated the mechanism of the transport from oleosomes to cells. As cells, we used model systems (liposomes) that mimic the outer lipid bilayer that the cells have. We forced the loaded oleosomes to come in contact with the liposomes and using spectroscopy and confocal microscopy we tracked the transportation of curcumin. About 35 wt% of curcumin molecules were swiftly transported from oleosomes into the liposome lipid bilayer within 5 minutes. The surface activity of curcumin played a significant role in its transportation towards the liposomes, since when non-interfacial active hydrophobic molecules were used (Nile red) no transportation towards liposomes took place. Our findings provide insights into the release mechanism of hydrophobic therapeutics from oleosomes and can lead to the design of new lipid carriers for efficient health treatments.

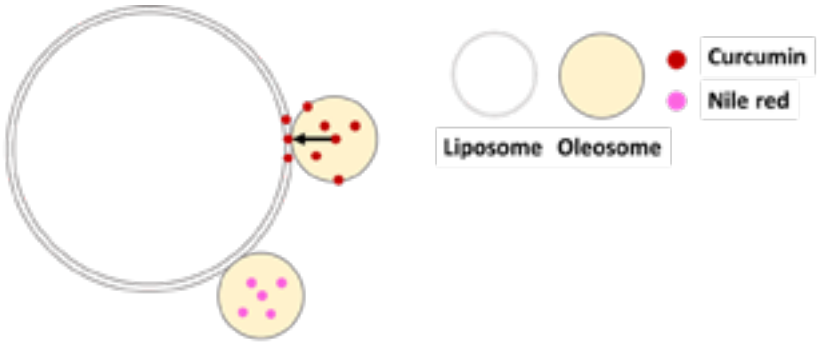

Figure 1. Illustration of hydrophobic molecules release from oleosomes to artificial cell bilayer (liposome)

Acknowledgments: This study was supported by the Republic of Türkiye Ministry of National Education

Dynamic assemblies of milk protein related to lactose crystallization in the solid state and their impact on the formation of colloidal dispersions 157

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ABSTRACT

Milk powders are good nutritional sources as alternatives to fresh milk, as well as food ingredients due to their techno-functional properties. They are expected to reconstitute into a stable colloidal dispersion to meet application requirements. Lactose crystallization is recognized as the primary cause of detrimental quality losses in milk powders, especially under challenging environmental conditions. However, the cause-and-effect relationship between lactose crystallization and colloidal stability is not well understood. Glassy lactose transforms to rubbery lactose and crystallizes into diverse phases, sizes and crystallinities depending on its surroundings; as a result, protein assemblage could change. This study aims at probing dynamic assemblies of milk protein related to lactose crystallization in the solid state, and evaluating the impact of the interaction between protein and lactose in colloidal dispersions.

Milk protein concentrate (MPC) was co-lyophilized with lactose at two ratios. MPC and lactose were also lyophilized separately, and then blended at the same ratios. Dynamic Vapor Sorption was used to characterize water absorption. The powders were stored at 43%, 53% and 75% RHs at 25oC for different periods ranging from 0 hour to 21 days. After storage, the powders were analyzed by Synchrotron Small- and Wide-Angle X-ray Scattering (SAXS/WAXS) to elucidate changes in protein and lactose. Fourier Transform Infrared Spectroscopy was used to probe the secondary structure of protein. Dynamic Scanning Calorimetry, Low-field Nuclear Magnetic Resonance and Scanning Electron Microscopy were used to characterize the glass transition, water mobility and microstructure respectively. The powders were reconstituted and subsequently measured using Mastersizer to comprehend colloidal dispersion. Varied water absorption profiles between co-lyophilized powder and its counterpart indicate interactions between lactose and protein. As lactose crystallizes, protein dynamically assembles dynamically, and some assemblages are irreversible, depending on lactose properties (Fig. 1). The re-assembling of protein is a direct cause of the unstable colloidal dispersion.

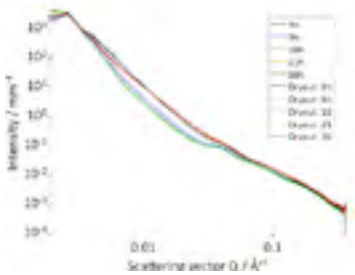

Figure 1. Assemblies of protein indicated by SAXS profiles

Acknowledgements: This work is fund by Innovation Fund Denmark and Arla Foods. We acknowledge also funding from Diamond Light Source grant SM34844 for access to SAXS/WAXS synchrotron facilities.

Study of the enzymatic hydrolysis of Tattarodes sagittatus by-products via interfacial tension measurements 173

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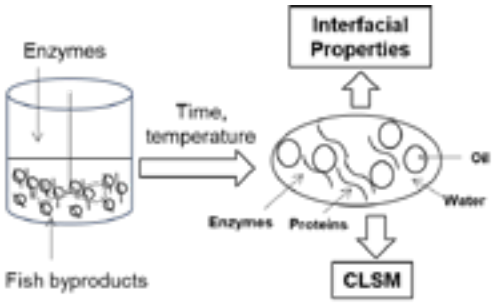
ABSTRACT

The fish industry generates a significant amount of by-products during fish processing including heads, bones, viscera etc., which are typically discarded as waste. However, these by-products can be a rich source of nutrients, including lipid, protein and minerals. One method employed for fish oil and extraction is enzymatic hydrolysis. Following the enzymatic hydrolysis process, the resulting substance is fractionated into four separation components: fish oil, emulsion, water phase rich in proteins and sludge.

This work investigates enzymatic activity on the oil/water interface via the measurement of oil/water interfacial interfacial tension and interfacial rheology. For this the most commonly used enzymes protease and alcalase were applied and Todarodes sagittatus bellies were used as a waste product. The measurements were used as means to comprehend the progress of the proteolytic action of the enzymes applied as aids to liberate the oil phase during oil extraction from the by-products. The results of interfacial properties are coupled with Confocal Laser Scanning Microscopy (CLSM) of the interface and correlated with the oil yield during the separation processes.



Acknowledgements: This research has been partly financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH— CREATE—INNOVATE (project code: T2ΕΔΚ-02465 – project title "Research and development of high nutritional value anti-inflammatory functional foods, enriched in ω-3 fatty acids sourced from Greek fisheries and farming byproducts".

Effect of emulsification temperature in structured emulsions with monoglycerides and Tween 20 179

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ABSTRACT

As the demand for plant-based alternatives continues to grow, the development of structured emulsion systems has gained significant attention in the food industry. Structured emulsions, formed by the synergistic interaction between monoglycerides and Tween 20, provide a valuable tool for addressing these issues. Monoglycerides (MGs) function as lipid-based structurants, while Tween 20, an emulsifying agent, aids in stabilizing the emulsion and enhancing its texture. Understanding the complex interactions between monoglycerides and Tween 20 is essential for tailoring structured emulsion systems to specific product requirements. This involves optimizing the composition and processing conditions to achieve the desired texture, stability, and sensory properties in plant-based foods.

The impact of homogenization temperature and ultrasonication intensity was studied. Crystalline structures of MGs and Tween 20 in aqueous solutions were formed. These structured emulsions and dispersions were characterized using Differential Scanning Calorimetry (DSC), rheology, polarized optical microscopy, and Confocal Laser Scanning Microscopy (CLSM). The results showed that homogenization temperature played a crucial role in stabilizing the emulsions, affecting their thermal properties and microstructure. Moreover, ultrasound intensity facilitated the crystallization of MGs, although to a lesser extent. When crystallization occurred in-situ, the system remained in a steady state during the experimental period as the crystals acted as Pickering particles, whereas pre-crystallization in water led to aggregation phenomena.

Acknowledgements: The research work was supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the "First Call for H.F.R.I. Research Projects to support Faculty members and Researchers and the procurement of high-cost research equipment grant" (Project Number: HFRI-FM17-3601).

Boosting Bubbles in Non-Alcoholic Beers: The Potential of Protein Hydrolysates, Beer Proteins, Iso-alpha-acids and CO^2 191

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ABSTRACT

Brewing non-alcoholic beers (NABs) requires various adaptations to the regular beer brewing process. These lead to changes in the chemical composition of NABs compared to alcoholic beers, which in turn affect their quality characteristics. One of these characteristics is the amount of bubbles, which is significantly lower in NABs than in alcoholic beers. Besides the visual appreciation, this lower amount of bubbles also influences the foaming properties, the bubbling sensation in the mouth, and even the perceived viscosity. Therefore, the aim of this study is to understand the influence of beer composition on the amount of bubbles, so that strategies can be developed that enhance bubble formation in NABs.

A comprehensive chemical and physical characterization of 19 commercial beers (9 NABs and 10 alcoholic beers) showed that their bubble density was mainly influenced by the CO2 content and the dynamic surface tension measured at a surface age relevant for bubble formation in a glass (200 ms). Increasing the CO2 content in beers might alleviate the problem of low bubble density in NABs, but this will alter the taste and sting as well. A second approach is the reduction of the surface tension at 200 ms. While the surface tension of beer at low surface ages appeared to be mainly determined by the alcohol content, beer proteins and iso-alpha-acids influenced the surface tension of NABs. Post-production process addition of protein hydrolysates to beer was found to reduce surface tension even at low surface ages, as they rapidly adsorb at the bubble interface. Addition of 1 g/L protein hydrolysates to NABs resulted in a similar bubble density as observed in alcoholic beers. This thus offers a potential solution to enhance the quality of NABs further. These insights can also be applied to improve the quality of various sparkling beverages.

The application of fucoidan for the encapsulation of Saccharomyces cerevisiae K2 toxin 206

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ABSTRACT

Consumer interest in minimally processed food, and "greener" food and beverage additives is increasing. This stimulates the search for new potential biopreservatives, i.e., natural substances exhibiting antimicrobial properties and isolated from plants or microorganisms. K2 toxin produced by food yeast Saccharomyces cerevisiae could have the potential as biopreservative [1]. Since K2 toxin is a protein, its antimicrobial activity can be reduced by proteolysis, interaction with other substances in food and other environmental stress. To avoid those side processes, encapsulation technologies can be applied.

The work aims to prepare and characterise fucoidan particles loaded with K2 toxin. Fucoidan is a water-soluble polysaccharide found in marine brown seaweeds such as Fucus vesiculosus, Macrocystis pyrifera, and others. The use of fucoidan has increased based on its antioxidant, anticancer, antibacterial, antiviral, and anticoagulant properties [2].

K2 toxin was purified from growth medium of yeast S. cerevisiae using ion-exchange chromatography on SP- and CM-Sepharose. K2 toxin-loaded particles were synthesized by a simple complexation method at pH values of 3.8, 4.2 and 4.8. The final concentration of fucoidan was 0.1 or 0.4 mg/mL and K2 toxin concentration was 3.0 or 4.6 µg/mL. FT-IR and DLS methods were used to confirm the interaction of components. The particle size was 180-260 nm at all pH values. The antimicrobial activity of K2 toxin-loaded fucoidan particles was tested against wine-related yeast contaminants from Candida, Zygosaccharomyces, Pichia and Saccharomyces genera by applying the agar-diffusion and direct survival assay. The most effective inhibiting activity of encapsulated toxin was detected against Saccharomyces cerevisiae yeast, which has been frequently associated with the refermentation of wines. The viability of other yeast strains tested, including the potential human pathogen C. albicans, was also reduced, but to a lesser extent.

Our data suggest that the developed yeast toxin formulation could be used in the food industry for biopreservation.

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[2] Venkatesan J., Murugan S. S., Seong G. H. Fucoidan-based nanoparticles: Preparation and applications. International Journal of Biological Macromolecules 217 (2022) 652-667.

Acknowledgements: This project has received funding from the Research Council of Lithuania (LMTLT), agreement No S-MIP-22-7.

Interactions between hexadecyltrimethylammonium bromide and poly(acrylic acid): effect of the polymer molecular weight 220

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ABSTRACT

Binary surfactant + polyelectrolyte mixtures have been widely applied in cosmetics, detergency, oil recovery, pharmaceutical formulations, and rheological control. Understanding the conformation and microstructure of these surfactant/polyelectrolyte complexes is essential for further practical applications of such mixtures.
The effect of polymer molecular weight on the interaction of hexadecyltrimethylammonium bromide (C16TAB) and poly(acrylic acid) (PAA) in bulk phase at a fixed 0.05wt% PAA was examined using isothermal titration calorimetry (ITC), zeta potential, pH value, and surface tension measurements. The saturated concentration, at which micellization of the surfactant onto the polymer in the bulk phase completes, the heat of complexation, heat of micellization, and critical micelle concentration for the onset of formation of free micelles in the bulk phase were determined from the ITC thermograms. In addition, the surface tension has been measured to investigate the adsorption and complexation at the solution interface. The results indicate that PAA/C16TAB complex formation is an exothermic process driven by electrostatic and hydrophobic interactions. Significant precipitation of interpolymer complexes was continuously observed for PAA molecular weight (MW) ≥130,000, and all of the derived critical micelle concentration, phase separation concentration, the heat of complexation, and the heat of micellization were MW-independent. At phase separation concentration, the complexes formed visible millimetric aggregates for PAA MW of 25,000. These aggregates eventually dissolved as more C16TAB was added, and the solution became clear again. Turbidity was seen in a wide range of concentrations for PAA with an MW of ≤5000, although no macroscopic precipitation was observed, and the solutions were always homogenous. In addition, the effect of PAA molecular weight on the microstructure of PAA aqueous solutions is discussed.

Influence of sonication on protein-polyphenol interaction and resulting protein functionalization 235

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ABSTRACT

For the purpose of sustainability, alternative plant-based protein sources are increasingly being used to replace animal-based proteins. However, extracting or isolating these proteins from raw materials requires a high level of processing. Additionally, the plant matrices contain secondary plant substances that might interact with the proteins depending on the process parameters. The interaction between protein and secondary plant products results in a modification of the physicochemical and functional properties of the protein in colloidal systems, as well as a change in behavior in downstream processes [1]. This study investigates the impact of sonication on protein-polyphenol interactions and the subsequent functionalization by heat-induced aggregation. This study uses beta-lactoglobulin as a reference protein and caffeic acid, representing a key compound in plant-protein concentrates. The heat-induced formation of protein aggregates is followed by particles size measurement using static and dynamic light scattering technics. During the aggregation process, the technological functions such as water- and oil-binding capacities are modified and are examined. Physico-chemical properties of the aggregates (e.g. secondary structure, protein oxidation, surface hydrophobicity and particle charge) are investigated by infrared and fluorescence spectroscopy as well as electrophoretic light scattering. The findings of this study can be used to better assess the effects of applied process parameters and the effect of residual plant compounds on protein functionalization in order to make them usable co-formulants for future food systems.

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Functionality of whey proteins covalently modified by allyl isothiocyanate. Part 2: Influence of the protein modification on the surface activity in an O/W system, Food Hydrocolloids, Volume 81, 2018, Pages 286-299

Physico-Chemical Characterization of Commercial Pea Protein Isolates for the Development of Vegan Meat Product Analogs 243

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ABSTRACT

Industry, science, and society have been witnessing a transition in the production and consumption of conventional meat products to plant-based meat substitutes for several years now. However, the use of wheat and soy protein in these products poses allergenic challenges. As a potential solution, pea emerges as a promising alternative protein source that offers low allergenicity, wide availability, cost efficiency, and good emulsifying and gelling properties. Commercially available pea protein isolate products can be extracted using various extraction methods such as alkaline extraction with isoelectric precipitation and salt extraction. As a result, the composition and functional properties of these products can differ. The applicability of a pea protein isolate product for meat analog development heavily depends on its physicochemical characteristics, such as pH-dependent surface charge, native pH, and protein solubility. Therefore, this study screened nine pea protein isolates that are commercially available to determine their composition, solubility at pH 7, and zeta potential across a range of pH values between 3 and 8. The solubility analysis results showed that the proportion of soluble protein to total protein differed between 9.24 ± 0.36 % (Cosucra, Pisane B9, Warcoing, Belgium) and 40.74 ± 0.94 % (Emsland Group, Empro E86 HV, Emlichheim, Germany).

Acknowledgements: This work (as part of the research project AiF 22862) was funded in partnership with the German "Forschungskreis der Ernährungsindustrie e.V." (FEI, Bonn, Germany).

RESIDUAL LIPIDS PRETREAMENT TOWARDS ALTERNATIVE FUELS PRODUCTION 248

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ABSTRACT

Waste cooking oils (WCOs) are a source of residual biomass and are generated from edible oils and fats during frying and cooking. It is estimated that ~17 million tons of WCOs are produced annually in the world, while in the European Union (EU) ~1 million tons, while 60% of it is improperly disposed. Poor management of WCOs exacerbates environmental pollution. Also, these degraded lipids can no longer be used, so new pathways of their utilization are being explored such as starting materials for surfactant production or biofuels. In this context and considering the intensive utilization of fossil fuels and the depletion of petroleum resources, the research interest is focused on new technological pathways leading to renewable fuels production. Towards this direction biofuels production from residual lipids and particularly WCOs is being investigated. However, waste lipids are highly heterogeneous and contain a variety of impurities affecting the potential valorization routes and there are specific standards that need to be fulfilled when WCO are employed for fuels production. The present study aims to investigate the pretreatment of residual lipids (WCOs), in order to improve their degraded qualitative properties prior their conversion into alternative fuels, under a circular economy concept. In particular, through a three-stage process (neutralization, washing and removal of soaps and drying), the properties of the WCOs were significantly improved, rendering these waste lipids appropriate to be further utilized.

Figure 1. Schematic diagram of WCOs pretreatment stages

Acknowledgements: This research has been funded by the European Union-Next Generation EU through the National Recovery and Resilience Plan Greece 2.0 (Project code: T2EDK- 00034 "Advanced alternative ground and air transport fuels from residual lipids– Lipid4fuel").

Impact of alginate block type on the structure and physicochemical properties of curcumin-loaded complex biopolymer nanoparticles 256

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ABSTRACT

In this study, core-shell complex biopolymer nanoparticles loaded with curcumin were fabricated using a simple pH-driven method. An aqueous solution containing curcumin, zein, sodium caseinate, and sodium alginate was prepared under a strongly alkaline condition (pH 12) and then acidified (pH 4). This led to the formation of curcumin-loaded complex biopolymer nanoparticles with a hydrophobic core (zein) surrounded by a hydrophilic shell (caseinate-alginate). The nanoparticles formed from β-D-mannuronic acid residues blocks (MM-blocks) had the smallest hydrodynamic diameter (202 nm), highest encapsulation efficiency (98 g/100 g), and best water-dispersibility. Transmission electron microscopy showed that the complex biopolymer nanoparticles had a core-shell structure. Fluorescence and FTIR spectroscopy were used to provide insights into the nature of the molecular hydrogen bonding and electrostatic interactions within the complex biopolymer nanoparticles. Overall, the curcumin-loaded complex biopolymer nanoparticles fabricated from MM-blocks had the best long-term storage and salt stability. These results may be useful for creating colloidal delivery systems that enhance the dispersibility, stability, and bioactivity of hydrophobic nutraceuticals.

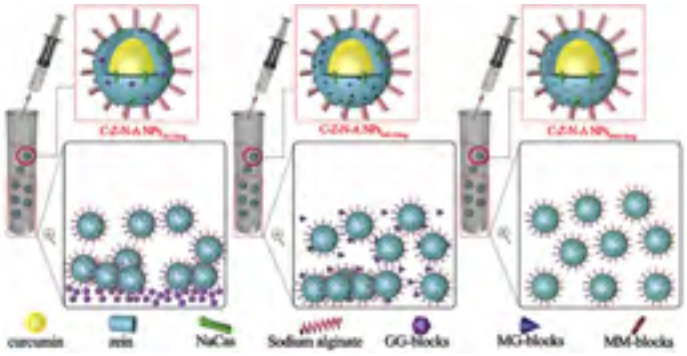

Figure 1. Curcumin-loaded complex biopolymer nanoparticles incorporating sodium alginate blocks (GG-blocks, MG-blocks and MM-blocks) have different structures and exhibit three different stable states in solution.

Acknowledgements: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Colloid-chemical properties of surfactant-nanoparticles mixtures in bulk and at the water/air interface 260

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ABSTRACT

The interaction between nanoparticles and surfactants is a key determinant in structuring the dynamic and static behavior of interfaces with significant implications across various industrial applications and academic research fields. In this study, we investigate the influence of hydrophilic silica nanoparticles on the colloid-chemical properties of surfactant systems, exploring anionic (SDS), cationic (DoTAB), and nonionic (Tween-65) surfactants. This research arise from the growing interest in understanding the complex interplay between surfactants and nanoparticles, especially in systems where untreated nanoparticles lack inherent surface activity. By using a comprehensive approach, covering surface tension measurements, rheological analyses, dynamic and static surface tension investigations, and zeta potential measurements, the study aims to gain a deeper understanding of the synergistic effects and optimize conditions for the utilization of nanofluids in various technological applications.

The surface-active properties, including surface tension and dilatational elasticity and viscosity, of surfactants (anionic, cationic, and non-ionic), nanoparticles, and their mixtures at the water/air interface were investigated. The study aimed to understand how these properties vary depending on the nature of the surfactants. The observed range of surfactant concentrations revealed the optimum expression of surface-active properties in the composites. Bulk properties of surfactants, nanoparticles, and their composites were also explored, unveiling distinct features influenced by factors such as salinity, pH, and the different nature of surfactants. The sizes (size distribution by intensity) and charges (zeta potential) of surfactants, nanoparticles, and their composites were examined concerning the presence of NaCl and various pH levels, along with composites featuring surfactants of different natures (cationic, anionic, and non-ionic). It was noted that an increase in surfactant concentration led to a reduction in composite sizes. The results regarding bulk properties correlated with the findings from the study of surface tension and dilatational rheology.

The observed changes in surface tension, rheological parameters, and zeta potential values highlight the importance of considering nanoparticle-surfactant interactions in optimizing nanofluid compositions for diverse technological applications. These findings provide comprehensive insights into the interplay of anionic, cationic, and non-ionic surfactants with nanoparticles, shedding light on how their surface and bulk properties are influenced by varying factors. This understanding is crucial for optimizing the formulation and performance of these composite systems in applications ranging from materials science to environmental engineering.

Changes in the molecular organization of model lipid membranes after geraniol incorporation 318

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ABSTRACT

Geraniol is an aliphatic monoterpene occurring in the ethereal oils of many plants species[1]. Its rose-like aroma makes it a popular choice in the production of food as a flavoring substance. It occurs naturally in some fruits. Among other things, it can be found in grapes in which it constitutes the main precursor of terpenes responsible for the aroma of white wines[2]. Geraniol has been shown to exert a wide spectrum of pharmacological activities, for example anti-inflammatory, antioxidant, antimicrobial activity. Besides that, numerous in vitro and in vivo studies have shown its anticancer activity[3].

The antitumor mechanism of action of geraniol is not fully understood, but it is suspected that one of the most important steps is its interaction with the cell membrane and changing its molecular organization. Therefore, the aim of the research was to determine the effects of geraniol at different concentrations on model lipid membranes composed of phosphatidylcholine (POPC), sphingomyelin (SM) and cholesterol, in systems with different cholesterol contents and a constant POPC/SM molar ratio (1:1). In studies were used Langmuir monolayers supported by Brewster angle microscopy and liposomal systems including calcein release experiments and steady-state fluorescence anisotropy of DPH.

The conducted research demonstrated that geraniol interacts with model cell membranes, and its incorporation into membranes is accompanied by changes in their physicochemical parameters, such as lipid packing, fluidity and permeability. The investigated monoterpene incorporating into the structure of lipid membranes disrupts the ordering in the area of hydrophobic chains causing their fluidization. Moreover, the obtained results indicate that cholesterol content in the membranes has significant impact on the incorporation of monoterpene into lipid membranes. This may show that molecular mechanism of geraniol action is connected with its interactions with sterol in lipid rafts, which are responsible for regulating cells functions.

References: [1] M. H. P. de Lira, et al., J. Essent. Oil Res., 2020, 32, 187-197.

[2] D. Steyer, et al., Food Microbiol., 2013, 33, 228-234.

[3] R.B. Armar, Molecules, 2023, 28, 3669-3682.

Acknowledgements: This project was financed by the Excellence Initiative – Research University at Jagiellonian University Young Labs 3 (U1U/W20/NO/17.24)

Effect of pH and ionic strength on the physicochemical properties of oat protein-polysaccharide self-assembly 323

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ABSTRACT

Recently, plant protein-based products are in demand as sustainable alternatives to animal products. Oat products in particular are often widely accepted due to their positive health benefits, combined with a low carbon footprint and allergen content. Nevertheless, the colloidal properties of oat protein have rarely been explored in the literature compared to other plant proteins, particularly when subjected to process-relevant physical and chemical conditions. Additionally, there is limited understanding of how oat protein and oat polysaccharide co-existing in nature may behave in food formulation and processing related conditions.

Herein, we explore fundamental colloidal properties of a "crude" oat protein extract when subjected to pH and ionic strengths. Oat crude extract was produced via alkaline extraction of defatted oat flour without further purification, i.e., in the presence of co-extracted soluble compounds including oat β-glucan. Extract characterisation via sodium dodecyl-sulphate polyacrylamide gel electrophoresis (SDS-PAGE) showed multiple protein bands, with the major fraction being 12S oat globulin (65-67 kDa). The presence of β-glucan in the extract was also confirmed via a spectrophotometric assay. To understand the effect of pH and ionic strength, particle size measurements were conducted using dynamic light scattering (DLS). Complementary zeta-potential (ζ) measurements confirmed the protein's negative surface charge at pH 7.0 and isoelectric point (pI) between pH 4.0-4.5. Preliminary results indicate a hydrodynamic size of ~100 nm of these protein-polysaccharide assemblies, with a polydispersity index of 0.2 and partial dissociation at pH values significantly above or below the pI. Analysis via circular dichroism (CD) spectroscopy revealed changes in oat globulin's secondary structure as a function of pH, which may be influencing protein-protein aggregation behaviour. Ongoing work is focusing on pinpointing the role of β-glucan in the self-assembly, with oat protein affecting responsiveness to pH and ionic strengths. Such knowledge can inform future sustainable food formulations without further purification.

Acknowledgements: Authors gratefully acknowledge the Engineering and Physical Sciences Research Council (EPSRC) funded Centre for Doctoral Training in Soft Matter for Formulation and Industrial Innovation (SOFI^2), Grant Ref. No. EP/S023631/1 for financial support. This work was co-funded by Oatly, UK.

Thermal treatment on lactoferrin affecting mucin-binding properties 325

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ABSTRACT

Mucins are glycoproteins that constitute the primary component of mucus, the gel-like layer on mucous membranes that covers various human and animal cavities. There has been a significant interest in understanding the interactions of dietary proteins with mucins, to tailor the development of foods without any undesirable astringency perception. Although there is existing literature on how dietary proteins generally interact with mucins, how the processing affects the protein and their binding with mucin remains less studied. This study focuses on understanding how thermal denaturation of proteins affects binding to mucin. We use lactoferrin (LF), a milk protein often used as a biofunctional food additive in infant formula as a model system. Given lactoferrin's tendency to denature at temperatures higher than 65 °C, we explore the impact of thermal processing on its structure and adsorption properties to bovine submaxillary mucin. A combination of circular dichroism (CD), rotational rheology, dynamic light scattering (DLS), sodium dodecyl sulfate- polyacrylamide gel electrophoresis (SDS-PAGE), and quartz crystal microbalance with dissipation monitoring (QCM-D) was used to elucidate structure-function relationships of lactoferrin undergoing various degrees of thermal denaturation. Results show that post-denaturation, the viscosity of a 1wt% lactoferrin sample remains unchanged, though circular dichroism indicates alterations in secondary structure content, as α-helix structures were converted into β-sheet. DLS measurements showed an increase in particle size, while SDS- PAGE confirms higher molecular weights after the thermal treatment of LF. Notably, the denatured lactoferrin exhibited stronger interaction with bovine submaxillary mucin (BSM) when compared to its native counterpart, as observed through adsorption measurements on a QCM-D sensor (Figure 1). These experimental investigations underscore the enhanced mucoadhesivity and potential astringency of denatured lactoferrin. This research contributes valuable insights into the dynamic interplay between lactoferrin and mucin as a function of thermal denaturation, paving the way for innovative applications in various food applications.

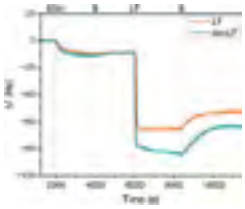

Figure 1. QCM-D frequency shift (5th overtone) using a PDMS-coated sensor, after adsorbing native (LF) or denatured (denLF) lactoferrin samples onto BSM layers. Shaded regions represent error bars (n=3).

After each adsorption, BSM and LF layers were rinsed with buffer (B).

Acknowledgments: Authors gratefully acknowledge the Engineering and Physical Sciences Research Council (EPSRC) funded Centre for Doctoral Training in Soft Matter for Formulation and Industrial Innovation (SOFI2), Grant Ref. No. EP/S023631/1 for the financial support provided. This work was co-funded by Reckitt Benckiser Group, Plc.

Preparation of electrospun fibers from aqueous mixtures of lysozyme and maltodextrin and morphology of the fibers 327

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ABSTRACT

The aim of the study was to prepare fibers from an aqueous solution of maltodextrin DE2 and lysozyme by needleless electrospinning and their characteristic morphological properties were investigated. Lysozyme is known for its antimicrobial activity [1]. Therefore, lysozyme was used to produce these fiber composites. The different conditions used were 80, 85, and 90 g of maltodextrin and 5, 10, 15, 20, and 25 g of lysozyme in 100 mL of ultrapure water. The electrospinning rate and yield, the protein concentration in the spinning solution and in the fibers, and the fiber diameter were determined by scanning electron microscopy (SEM). Fourier transform infrared spectroscopy (FTIR) was used. The highest spinning rate was observed in spinning solution using 80 g maltodextrin and 20 g lysozyme (80-20) with 7.6±0.03 g/h. The lowest spinning rate was 1.93±0.01 g/h for 80-15 (maltodextrin/lysozyme). Overall, all spinning solutions were found to spin successfully. Determining the protein content in the spinning solution and in the fibers showed that increasing the protein concentration led to a decrease in the protein content in the fibers. The decrease ranged from 11.11% (80-10, 85-10 and 90-10) to 12.78% (80-25, 85-25 and 90-25). Visual examination using a SEM showed that sample 85-10 had the smallest diameter of 3.63±1.18 µm, while sample 90-25 had the largest diameter of 5.95±4.03 µm. It was observed that the fibers with the highest protein content (80-25, 85-25, and 90-25) had larger diameters than the fibers with the lowest protein content (80-5, 85-5, and 90-5). The structure and surface of the fibers were mostly smooth, with occasional bead formation and thicker or thinner areas within a fiber. FTIR analysis showed that there was no further chemical reaction between maltodextrin and lysozyme in the fibers. Overall, it was observed that lysozyme was well incorporated into the maltodextrin fibers.

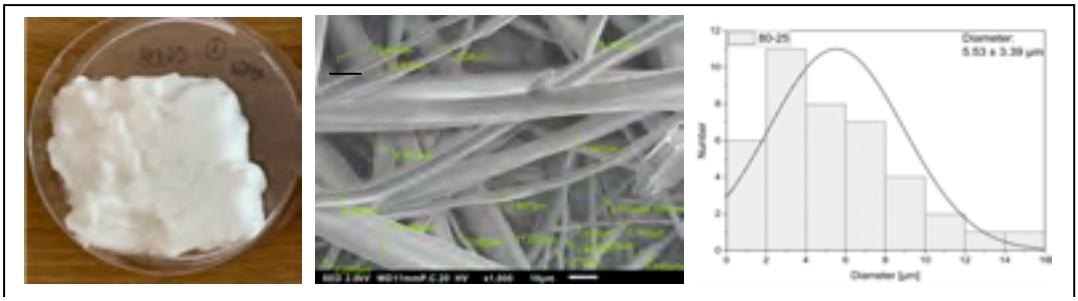

Figure 1. (a) Electrospun fibers (80-20 / maltodextrin-lysozyme), (b) SEM image of fibers (80-25), and (c) histogram of the diameters of electrospun fibers (80-25)

References: [1] Masschalck, B. and C. W. Michiels (2003), Critical reviews in microbiology 29(3): 191–214

Patchy particles as a model system to understand protein aggregation 332

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ABSTRACT

We investigated the structure formation in synthetic and protein model colloidal particles. As synthetic model particles we use di-patch and tetra-patch colloids to model the specific bonding of molecules. We employ critical Casimir forces to achieve tunable attraction and add sucrose to the binary solvent to reach denstiy matching. We find that the patchy particles form a 3D network and are well distributed in space even on a long timescale. By locating and tracking the particles in 3D we can reconstruct the system and understand cluster alignment and growth.

We also study network formation using whey protein microparticles as the experimental system. In this model system, the proteins are pre-clustered in micrometer-sized colloidal proteins, and aggregation is followed in 3D space upon lowering the pH to obtain insight into protein gelation for food applications.

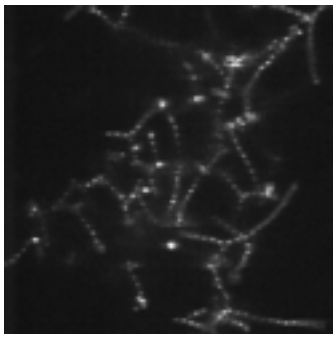

Figure 1. Confocal image of 3D network of patchy particlces

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Acknowledgements: This project is funded by China Scholarship Council.

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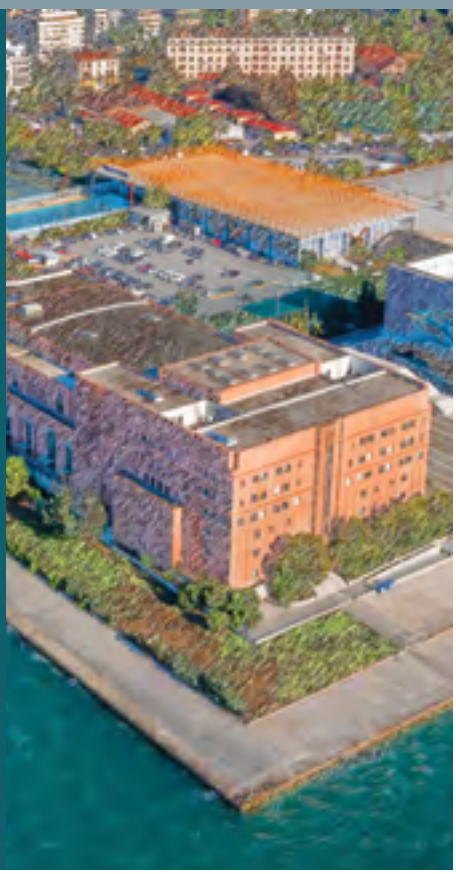

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