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A Colloidal suspensions

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Improvement of emulsification properties through physicochemical changes of porcine myofibrillar proteins induced by non-thermal physical treatment

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Phosphates are widely used food additives in the manufacture of processed meat. However, recently, as consumers become more interested in health and well-being, the demand for clean label products is increasing. Therefore, in this study, as part of the development of a phosphate substitute, the structural, rheological, and emulsifying properties of porcine myofibrillar proteins were investigated after sonication, a non-thermal physical treatment method. Through DLS (dynamic light scattering) analysis and SDS-PAGE (sodium dodecyl sulfate-polyacrylamide gel electrophoresis), it was confirmed that the particle size of the protein significantly decreased compared to the initial stage after non-thermal physical treatment for each condition. Through Fourier-transformed infrared spectroscopy and circular dichroism spectroscopy, it was confirmed that the secondary/tertiary structure of the protein was modified after sonication treatment. In addition, hydrophobicity of the protein was increased and turbidity was improved by sonication. As a result of analyzing the rheological properties of the protein solution before and after physical treatment using a rheometer, all samples showed shear thinning behavior and had a gel-like structure with a storage modulus higher than the loss modulus. Furthermore, it was confirmed that the emulsification activity index and the emulsification stability index of the sonicated porcine myofibrillar protein were improved, and spherical droplets were well formed through confocal laser scanning microscopy images. These results will serve as the basis for future research on the use of porcine myofibrillar protein as a substitute for phosphate as part of clean label materials.

Rheological properties and secondary structure changes of quinoa proteins impacted by the incorporations of anionic polysaccharides at various pH and ionic strength

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Protein and hydrocolloid complexation involves non-covalent interactions facilitated mainly by electrostatic interactions. Thus, the type of hydrocolloid, concentration, ratio, pH, and ionic strength conditions are crucial parameters for mediating protein-hydrocolloid complex properties in aqueous systems. The viscosity and viscoelastic properties of electrostatic complexes are also influenced by the structure of proteins with preferential interaction with unordered parts of the hydrocolloid chains. The objective of this study was to understand the role of interactions between proteins and ionic hydrocolloids in inducing an increase in viscosity. Rheology and structural characteristics of quinoa protein isolate (QPI) suspensions and complexes with two anionic polysaccharides [xanthan gum (XG) and pectin (PEC)] were analyzed as a function of pH and ionic strength. Properties in terms of surface charge, hydrophobicity, the solubility of proteins, and the rheology behavior of suspensions were determined. Also, the secondary structure of QPI was examined by FT-IR spectroscopy. The results showed that the type of anionic polysaccharide significantly impacted the increase of viscosity of QPI suspensions. The XG exhibited the most strengthening effect of the complex network increasing the viscosity and elastic component (G´) of QPI suspensions. Probably was due to GX undergoing conformational transitions from helix to the random coil state, in response to pH stimuli, promoting more structure network formation. A maximum viscosity was found at pH 3.0 compared with pH 7.0 or 8.0, in which the attractive electrostatic interactions between proteins and ionic hydrocolloids are stronger. The ionic strength did not significantly impact the increase in the viscosity of the protein-ionic hydrocolloid systems. Increasing ionic strength diminished the interaction of protein and anionic polysaccharides. The were no significant differences in protein secondary structure between quinoa complex with XG and control samples. Even though, FT-IR studies suggested that QPI-XG and QPI-PEC electrostatic associations induced different conformational changes in the hydrocolloid backbone and QPI tertiary structure as a function of pH and ionic strength. The research would enrich the QPI applications in plant-based texture-modified beverages. Understanding rheological behavior is especially important during food processing to control the stability and sensorial acceptability of food/beverage products.

Impact of temperature on sensorial texture perception and rheological behavior of a lipid-based paste: Plumpy'Nut®

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Plumpy'Nut®, a Ready-to-Use Therapeutic Food (RUTF), is a lipid-based paste dedicated to the nutritional rehabilitation of children suffering from severe acute malnutrition. This complex blend contains primarily peanuts, sugar, vegetable oils and dairy powders. Some of its properties are comparable with various lipid-based spreadable pastes (ex., peanut butter). Because Plumpy'Nut® is used all over the world, this product can be consumed in different environments and, in particular, at various temperatures. Thus, it is critical to know how the temperature acts on its texture and overall organoleptic perception.

In this work, we will focus on the impact of temperature on the texture and oil perceptions of Plumpy'Nut® by a sensory panel, associated with instrumental analyses (indentation and rheology) in an attempt to describe the underlying physical mechanisms. Textural parameters (firmness, stickiness) were determined and analyzed as a function of the temperature by Texture Profile Analysis. In addition, the rheological properties were studied according to temperature (20°C to 60°C) to evaluate the dynamic viscosity of the product. In the meantime, calorimetric measurements were performed to understand oil crystallization state in the matrix at these temperatures, as it plays a key role in the texture modulation of Plumpy'Nut®. Sensorial and instrumental results are compared in order to check the possibility for finding correlations and describe the role of the structural properties of Plumpy'Nut® in texture and oil perceptions.

Analysis of non-linear rheological properties of Pickering emulsions stabilised with crystalline starch fractions

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Emulsions are dispersion systems of two immiscible liquids, which results in low stability. The production of emulsions requires the use of suitable hydrophilic or hydrophobic emulsifiers that prevent their destabilisation by locating on the interfacial surface. Solid particles can also be used to stabilise dispersion systems. Starch, cellulose or chitosan particles, as well as many others, have been used successfully. Solid particles can also be used to stabilise dispersion systems. Starch microfractions, cellulose or chitosan microfractions, as well as many others, have been used successfully. Crystalline starch fractions can be obtained, among others, by acid or enzymatic hydrolysis, precipitation or using ultrasound. In this study, an attempt was made to stabilise Pickering emulsions using crystalline starch fractions and edible oils. The crystalline starch fractions were obtained by an acid method carried out with sulphuric acid (VI) using waxy corn starch. Individually, vegetable oils, i.e. grape seed oil, sunflower oil, rice oil and olive oil, were used as the oil phase, while distilled water was used as the aqueous phase. Emulsions were produced using a laboratory mechanical homogeniser. Different proportions of starch microfractions were used with an unchanging water/oil ratio. The emulsions obtained were subjected to rheological properties with analysis of non-linear rheological properties. The emulsions obtained were characterised by high stability (at least several months), and therefore the crystalline fractions from waxy maize starch can be successfully used to stabilise dispersion systems produced on the basis of edible oils. On the basis of the analysis of non-linear rheological properties, it was found that elastic properties dominated over viscous properties for the obtained emulsions.

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Surface properties of protein concentrate with faba bean (Vicia faba L. minor)

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Faba bean protein fractions were extracted to obtain a concentrate of 83% protein. Physical and chemical tests of the obtained concentrate were carried out in the pH range of 2-9. The hydrodynamic radius was determined by DLS and the second virial coefficient by membrane osmometry. Measurements of surface and interfacial tension (protein solution - rapeseed oil) were performed using the pendant drop method. The tests were performed for a wide range of protein concentrations in the solution. This allowed the determination of the 2D equation of state on the Gibbs adsorption isotherm and the solution of the diffusion equation. Next, the influence of pH on the second virial coefficient and on the surface properties of the tested solutions was discussed. Studies revealed the existence of two pH values corresponding to Theta conditions and a strong relationship between the second virial coefficient and surface tension.

Effect of temperature during production and storage of monoglyceride oleogels

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Oleogelation is a promising approach to reduce the amount of saturated fatty acids is solid-like fats without losing its structure. Within the field of oleogelation, different hardstocks are used to structure the fat mixture that is rich in unsaturated fatty acids. Different hardstocks requires different structuring routes to form a three dimensional network that entraps the liquid oil. One of the promising methodologies is the use of monoglycerides (MAG) given their ability to form a gel at low concentrations. This research includes a follow-up study of two dynamically produced MAG-based oleogels. Both oleogels contained 6% of a monoglyceride hardstock (fully hydrogenated rapeseed oil) in rapeseed oil and were stored at 5, 15 and 20°C for 8 weeks. Differences in the cooling rate during production resulted in differences in the formation of the fat crystal network that was analyzed with polarized light microscopy (PLM), rheology, oil binding capacity (OBC) test and X-ray scattering techniques after a storage time of 1 week, 4 weeks and 8 weeks. Generally, the differences between the two oleogels were more pronounced compared to the differences as function of the storage time and temperature. The microstructure of the oleogel produced with the lowest cooling rate (MO1) showed large crystals compared to the dense crystal network of MO2. Additionally, these findings were also observed on the nanoscale. The crystal nanoplatelets of MO1 contained more lamellae compared to the nanoplatelets of MO2. These large crystals of MO1 were not able to hold the liquid oil resulting in an oleogel with a low oil binding capacity, rigidity and yield stress. These results showed that the stability of monoglyceride oleogels largely depends on the production process and less on the storage conditions.

NUTRAVA® Citrus Fiber can stabilize oil-in-water emulsions even in the presence of up to 4% Salt and in the presence of Calcium

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Supporting dietary fiber intake, NUTRAVA® Citrus Fiber is a clean-label friendly ingredient produced by sustainably sourced citrus peels, a byproduct of the fruit juice industry. NUTRAVA® Citrus Fiber contains fiber, pectin and protein, which enable unique water-binding, texturizing and stabilization capabilities. Interestingly NUTRAVA® Citrus Fiber can be used as an emulsifier to stabilize oil-in-water emulsion. In this study the impact of different parameters, such as use level of NUTRAVA® Citrus Fiber, oil fraction, various oil sources, pH and ionic strength on the physical properties of emulsions, were investigated. The data show that NUTRAVA® Citrus Fiber is a robust stabilizer for a wide range of emulsion systems. By varying its use level, it is even possible to easily fine-tune the rheological properties, such as viscosity, yield stress and complex modulus. By using MODDE software, we build a systematic map to reveal relationships between composition and physical properties, so we can guide the future NUTRAVA® Citrus Fiber users how to utilize it in applications.

Stability, rheology and morphology of O/W emulsion stabilized with PGPR-lecithin

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Emulsifiers such as polyglycerol polyricinoleate (PGPR) and lecithin are commonly employed in the production of emulsion-based foods. The appropriate composition of lecithin and PGPR blends in emulsions is obviously dependent on processing conditions and desired product attributes. The usage of lecithin-PGPR blends, on the other hand, opens up a world of options for modifying the flow properties of fat-based fillings, confectionery coatings and melted chocolate. The flow characteristics may be flexibly modified to meet individual processing and engineering demands, leading in increased product quality and economies. Therefore, the current experiment sought to ascertain the effects of various, systematically varied combinations of PGPR and lecithin on the flow characteristics of model chocolate in order to identify the best performance of the emulsifier blend. As a results, the effect of adding lecithin/PGPR combinations at 2/1, 2.5/1, and 3/1 ratios on food emulsions was examined in this study.

Rare sugars as sucrose replacers in biscuits: sweetness and texture perception

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There is growing emphasis on the use of rare sugars (e.g., D-allulose and tagatose) due to their lower calorific value and glycaemic response than sucrose, as well as similar sweetness levels. This study explores the use of D-allulose, tagatose and fructose as sucrose replacers in biscuits. The biscuit fracture strength and fracturability (3-point bending test), sensory profile (n=13, trained panel) and in vitro sugar release (ion chromatography) were evaluated. In addition, oral processing behaviour was measured using video recordings (n=10; number of chews and chewing duration) for sucrose and tagatose biscuits only. Overall results found that sucrose biscuits were more sweet, harder and crunchier as well as less mouthcoating and pasty compared with the other sugars. In terms of physical properties, tagatose biscuits demonstrated higher fracturability, lower fracture strength and an asymmetrical shape whereas sucrose biscuits had the opposite trend. In addition, sucrose biscuits had greater amounts of in vitro sugar release relating to mono and disaccharides that diffuse from the crumbled biscuit to water than the other tested sugars. Similarly, there were significant differences between sucrose and tagatose for the number of chews and chewing duration; the tagatose biscuits needed more chews and had a longer chewing duration than the sucrose biscuits. In summary, rare sugars modulated the sensory, texture, in vitro sugar release and oral processing behaviour of biscuits; accordingly, future work should focus on reformulation strategies that mitigate changes in the structure formation during mixing and baking, thus providing a similar oral processing experience as sucrose biscuits.

All-aqueous emulsions stabilized by sporopollenin exine capsules

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Nature provides a variety of materials that can be used in the design of novel food structures. One of those materials is pollen and plant spores, i.e., *Lycopodium clavatum* spores, which consist of an inner cellulose layer (intine) and an outer sporopollenin layer (exine), both of which are coated by lipids. Removing the inner components provides hollow particles composed only of the exine layer, which are known as sporopollenin exine capsules (SpECs). As novel food-grade particles, we investigated their ability to stabilize all-aqueous emulsions through a Pickering mechanism. The all-aqueous emulsions were prepared by mixing polyethylene glycol (PEG) and dextran (Dex) and allowing the system to phase separate into two aqueous phases by depletion interactions. SpECs were able to stabilize these all-aqueous emulsions and retard the phase separation process. However, the stability was shown to depend on the phase in which they were initially dispersed. A stable emulsion was obtained only when the SpECs were initially dispersed in the PEG phase. Confocal microscopy indicated that the SpECs were adsorbed at the surface of Dex droplets, dispersed in a continuous phase of PEG. The pH was also shown to play an important role in the stability; stable emulsions were formed at pH 7, but no stable emulsions could be obtained at pH 2 and pH 4. These results were attributed to the high ζ-potential (-31 mV) of the SpECs at pH 7, enabling them to electrostatically stabilize the emulsions after adsorption at the water-water interface. These findings show that there are unique particles in nature that may serve as colloids in the design of different types of foods.

Physics of Native and Modified Starch: Development of Biophysical Model Systems Explaining the Large Amplitude Oscillatory Shear Behaviour

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Understanding the structure-functionality of starch is very important for its targeted food applications. However, modification of starch is beneficial for improving functionality and reducing digestibility in diabetes and obese patients. Therefore, given that starch is a complex food system, it is advantageous for specific food applications to have a systematic and in-depth understanding of the viscoelastic properties of modified starch systems.

In this study we developed different biophysical models for explaining the elastic and viscous behaviour of native and modified starch systems. A physical modification technique called hydrothermal treatment was applied using different heating sources to modify the structural and rheological properties of starch extracted from underutilized tropical tuber crop, viz. elephant foot yam. It was found that hydrothermal treatment promotes the generation of short amylose by local breaking of α-1,4 glycosidic bonds of amylopectin and leads to the formation of short amylose crystals. Furthermore, large amplitude oscillatory shear (LAOS) behaviour was performed to understand the predominating solid-like behaviour in modified starch. The results entail the increased structural rigidity due to the formation of transient network structures in modified starch. Moreover, Lissajous-Bowditch plots confirm the early deviation of the structural integrity from elastic to viscous behaviour in modified starches as compared to its native counterpart. We also showed in our model systems that how the formation of stable and embedded amylose nanocrystals in modified starch paste contributes to the resistant starch fractions. Between the branched polymers, the short chain amylose alters the local molecular mobility and functions as a lubricant and effects the mechanical properties of modified starch which is clearly depicted in LAOS measurements. The details of the different shapes between the Lissajous plots come from the ratios of the concentrations of short chain amylose, long chain amylose, nano crystals etc. and the developed knowledge will be beneficial for future applicability of modified starch in formulating functional food products.

Using coacervation to develop functional plant protein based ingredients from unprocessed leguminous flour mixtures

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The heightened need and desire towards a more plant based diet has increased the demand towards functional plant protein ingredients. For industrial manufacturing, the majority of ingredients are manufactured through isoelectric or salt precipitation. These extreme processing conditions result in high polydispersity in particle size distribution and lowered functionality.

In the current research, we show that the leguminous proteins exhibit a general tendency towards coacervation, an intermediate stage in liquid-liquid phase separation. This spontaneous process is triggered on lowering electrostatic repulsion, indicating their pH and ionic strength dependance. Furthermore, we demonstrate the universality of coacervation using soybean, pea, and fava beans as model systems with leguminous flours a minimally processed unpurified mixture.

Different concentrations (15%, 18%, and 21% w/w flour dispersions) of soy, pea, and fava plant storage proteins were solubilized in alkaline conditions. On acidification (pH 8.0 to 4.8) of these protein dispersions, the proteins transitioned from soluble protein fractions to coacervate droplets and later aggregated.

The macroscopic appearance of samples show a clear rise in turbidity of protein dispersions' from soluble to insoluble domains, with the formation of coacervate droplets preceding aggregation. Bright field and CLSM images reveal that the coacervates exhibit the usual spherical domains and a homogeneous protein distribution. The study also observes the transition from coacervation to aggregation, with an intermediate phase of coacervates adhering to one another before complete aggregation. The particle size distributions illustrate a distinct transition with a Gaussian dispersion and the establishment of the previously described three domains, soluble protein fractions, coacervate droplet fraction and aggregated fraction.

We also observe protein fractions' specific affinity for coacervation but lack complete fractionation. Significantly, as the samples approach the isoelectric point, the overall dry matter content of the protein dispersions gradually increases. The results from the current research can be used to design ingredients with specific properties and applications to develop the next generation of plant-based foods.

Utilization of artificial intelligence to predict the rheological properties of hydrocolloids under different processing conditions

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A number of hydrocolloids have been extensively used in order to control the rheological properties of food products due to their unique features such as gelling, thickening, and stabilizing features. However, there are no mathematical models that can be universally applied to a wide variety of hydrocolloids with different rheological patterns. Therefore, if there is an efficient way to predict the rheology of hydrocolloids, it may be a breakthrough innovation in the food processing industries.

A machine learning framework was thus proposed in order to describe the flow behaviors of six hydrocolloid solutions. Furthermore, the hyperparameters of the machine learning model were tuned for accurately predicting their steady shear viscosities. Different shear-thinning and Newtonian behaviors were clearly observed depending on the type of hydrocolloids and shear rates. Methylcellulose exhibited a distinct viscosity pattern, which increased with increasing temperatures, compared to the other hydrocolloid samples. When the steady shear viscosities were subjected to rheological constitutive and machine learning models, the machine learning algorithms (random forest and multilayer perceptron models) showed a better fitting performance than the constitutive equations (Power-law and Cross models). In addition, three hyperparameters of the multilayer perceptron model (optimizer, learning rate, and the number of hidden layers) were optimized using a Bayesian algorithm, leading to the superior performance of the viscosity prediction by showing high R2 and low RMSE values.

Elucidation of starch recrystallization-induced quality changes in pre-cooked rice noodles under different storage conditions

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Pre-cooked noodles with long shelf-life and cooking convenience have been recently receiving a lot of attention in the global food market. However, thermal treatments during preparation and their high moisture contents bring about critical quality losses during storage, that have not been systematically evaluated yet.

In this study, the quality changes of the pre-cooked noodles made from rice flour were investigated in terms of thermal, tomographical, and water mobile characteristics. In particular, their physicochemical changes were monitored under different storage conditions (room temperature, refrigerated, and frozen) for 4 weeks. The T2 relaxation time and signal amplitude of the pre-cooked noodles were prominently changed during the refrigerated storage, showing water syneresis from starch recrystallization. In addition, the texture properties were highly correlated with the results of water mobility, presenting higher hardness and lower extensibility. Furthermore, non-destructive tomographical analysis demonstrated higher structural density and thickness of refrigerated noodles, which were correlated with the microstructural images by SEM. Furthermore, the higher degree of starch recrystallization was thermally observed in the refrigerated noodles during storage, followed by room temperature. This result might provide more fundamental information on the quality changes of pre-cooked noodles during storage, probably contributing to the quality improvement of pre-cooked starchy food products.

Overview of the potential of neutron scattering techniques to understand food systems

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Scattering techniques with neutrons and x-rays provide an unique view into the fascinating world of interfaces and networks provided by proteins and lipids. Contrast variation in neutron scattering additionally allows to catch a glimpse into the structure as well as motion of parts of the interface, e.g. in food emulsions.

Small angle scattering (SANS – with neutrons or SAXS – with X-rays) is ideally suited to study the structure, relevant length scales, correlation lengths and crystalline ordering from molecular to macroscopic distances. Examples are given from emulsions and derived products such as cheese and yoghurt. The power of contrast variation is illustrated with the use of deuterated oil and water to highlight or obscure parts of the interface. Neutron spin echo (NSE) spectroscopy provides the ultimate energy resolution in quasi-elastic thermal and cold neutron scattering spectroscopy. In terms of Fourier-time (τ) – or equivalently in terms of the accessible energy (E) – high resolution means the extension of τ (respectively E) into to the regime of μs (neV). This is the time range relevant for thermally driven fluctuations in biology and soft matter and allows to investigate protein dynamics or interface fluctuations in emulsions. This contribution aims to highlight instrumental aspects and opportunities provided by scattering techniques in the area of food emulsions and gels.

"No sugar coating it" - Vibrational spectroscopy approaches to locating amorphous sugars in biscuits

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One of the main ingredients in bakery products like cookies and cakes is sugar, which constitutes up to 30-40% sugar of the total recipe.[1] Sugar is a vital component, contributing not only to sweetness, but also impacting the structural and textural properties of biscuits.[2,3] During baking, the presence of crystalline sucrose in biscuit dough is thought to be functionally important, one distinct property of sucrose is its tendency to crystallise.[4] Sugar crystallisation takes place at the surface of the biscuit already during baking.[5] As sugar crystallises, it releases water and leads to the surface of the biscuit becoming dry. This leads to moisture gradients which may be linked to the structural integrity of biscuits.[6] By better understanding the state of sugar in biscuits, we may obtain a more complete understanding of its impact on the overall microstructure. Leading on from this, we may be able to modulate crystallinity to tune the physical properties of biscuits. The common techniques used to obtain qualitative and quantitative information about crystallinity include X-ray diffraction (XRD), differential scanning calorimetry (DSC), and plane-polarised light microscopy.[7] Vibrational spectroscopy, notably Raman and FTIR spectroscopy, have been increasingly used to quantify small amounts of amorphous materials in the pharmaceutical industry, however this has been underutilised in the food industry.[8, 9] The techniques that we have employed to study crystallinity in biscuits include ATR-FTIR, FTIR microscopy, and Raman spectroscopy. Additionally, deuterium exchange was used to isotopically label amorphous lactose and sucrose, Raman spectroscopy was used to monitor H/D exchange in these sugars. Lactose and sucrose were ideal sugars to monitor, as they have labile hydrogens which readily exchange with deuterium. Furthermore, these sugars are very much relevant to the food industry, the physical state of sucrose has a direct impact on the quality of many food products, like biscuits.[10]

1. R. G. M. van der Sman and S. Renzetti, Critical Reviews in Food Science and Nutrition, 2019, 59, 2225-2239.
2. K. Kawai, K. Hando, R. Thuwapanichayanan and Y. Hagura, Lwt-Food Science and Technology, 2016, 66, 384-389.
3. B. Pareyt, F. Talhaoui, G. Kerckhofs, K. Brijs, H. Goesaert, M. Wevers and J. A. Delcour, Journal of Food Engineering, 2009, 90, 400-408.
4. A. L. Voelker, G. Verbeek, L. S. Taylor and L. J. Mauer, Food chemistry: X, 2019, 3, 100050-100050.
5. S. Chevallier, P. Colonna, A. Buleon and G. Della Valle, Journal of Agricultural and Food Chemistry, 2000, 48, 1322-1326.
6. Q. Saleem, R. D. Wildman, J. M. Huntley and M. B. Whitworth, Proceedings of the Royal Society a-Mathematical Physical and Engineering Sciences, 2005, 461, 2135-2154.
7. P. Verma, N. A. G. Shah and S. M. Mahajani, Food Analytical Methods, 2020, 13, 2087-2101.
8. A. M. Tudor, S. J. Church, P. J. Hendra, M. C. Davies and C. D. Melia, Pharmaceutical Research, 1993, 10, 1772-1776.
9. A. Kapourani, V. Valkanioti, K. N. Kontogiannopoulos and P. Barmpalexis, International Journal of Pharmaceutics-X, 2020, 2.
10. K. M. Leinen and T. P. Labuza, Journal of Zhejiang University. Science. B, 2006, 7, 85-89.

Understanding the role of water-extractable wheat flour constituents in determining bread loaf volume

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Gas cells in bread dough are primarily stabilized by the viscoelastic gluten-starch (GS) matrix. Besides this, water-extractable flour constituents (such as proteins, lipids, carbohydrates, and minerals) are believed to also contribute to gas cell stabilization. Although it has been shown previously that such flour constituents positively influence bread specific volume (SV), it remains to be investigated whether this effect is caused by an altered dough bulk rheology and/or by a direct gas cell stabilization mechanism, whereby surface-active constituents adsorb at gas cell interfaces. Furthermore, insights about the individual roles of specific flour constituents (especially proteins) and their interplay in stabilizing gas cells in bread dough are lacking.

To this end, wheat flour aqueous extracts (WFAE) were prepared and subsequently modified by (i) dialysis (WFAE-D), to remove low molecular weight (LMW) constituents, and (ii) incubation with carbohydrate-degrading enzymes followed by dialysis (WFAE-EH,D), to remove carbohydrates and LMW constituents. This resulted in samples with varying chemical compositions. To study the role of water-extractable flour constituents in bread making, the different WFAEs were added to a model GS dough formulation. The dough gas cell size distribution and uniaxial extensional rheology were analyzed using X-ray micro-computed tomography (μCT) and a strain-controlled rheometer equipped with an extensional viscosity fixture, respectively, and were related to bread SVs after baking.

The protein content increased from 33% in WFAE to 61% and 82% in WFAE-D and WFAE-EH,D, respectively. Compared to WFAE, WFAE-D had a higher arabinoxylan (AX) content with a higher average degree of polymerization (avDP) but low polymeric glucose, ash, and fructan contents. WFAE-EH,D had substantially lower AX content than WFAE-D and WFAE. The addition of WFAE or WFAE-EH,D in GS bread recipes resulted in a significant bread SV increase relative to the control (+ 17%, $p < 0.05$), suggesting that WE-proteins may play a positive role in determining bread SV. Meanwhile, the addition of WFAE-D did not lead to a bread SV increase, which is likely related to the enrichment of AX with high avDP in this GS bread. Initial μCT data showed that GS doughs with WFAE-D or -EH,D seemed to have a higher number percentage of small gas cells than the control GS dough, possibly providing more gas nuclei for expansion during fermentation in these doughs. Rheological experiments showed that the control dough and dough with WFAE had similar linear and non-linear transient extensional viscosities and thus comparable resistance to deformation as a function of strain (i.e. dough strength). Conversely, WFAE-D or -EH,D addition to GS doughs had a significant dough-strengthening effect relative to the control dough ($p < 0.05$). In conclusion, the positive influence of WFAE constituents (specifically proteins) on bread volume seems to be related to an altered gas cell size distribution and the strengthening of the dough. To confirm these observations, the gas cell size distribution of these doughs will be characterized and similar experiments with other cereal flour aqueous extracts of varying chemical compositions will be performed, among others.

Characterising paste rheology for process optimisation

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Achieving consistent product quality without compromising productivity when the quality of raw ingredients varies is a challenge, particularly when supply chains are disrupted by a pandemic or geopolitical disruptions. In chocolate-making maximising refiner throughput is critical to productivity. The refining process involves roller milling paste made from sugar, dairy powder, and cocoa ingredients (fat and liquor) to achieve the desired particle size required to give the smoothness that is expected from chocolate. Minimising the amount of fat in the paste increases productivity, to a point where the mass transfer of material through the refiner is reduced. This study aimed to develop analytical methods to determine the optimal level of fat to maximise roll coverage for pastes made from sugar with different particle size distributions.

The dry ingredients flowed freely but viscosity increased as the level of fat was increased. At a critical fat level, which was dependent on the particles size distribution and shear rate, the system jammed and measurement of viscosity was not possible. Further addition of fat allowed the system to flow. By using serial dilution it was possible to estimate the void volume in the system from the viscosity.

Assessment of the rheological properties of thick puree dishes for patients with oropharyngeal dysphagia

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Background. Texture-modified diets are the first-line compensatory strategy for patients with swallowing and/or mastication disorders. However, the lack of a protocol to assess its textural properties burdens its standardization, quality control, and patient safety.

Aims: To assess: a) the rheological and textural properties of 10 thick puree dishes (texture C, British Dietetic Association (BDA); and b) the effect of oral processing (OP) and the properties of the bolus ready-to-swallow in healthy subjects.

Material and Methods. Shear viscosity (SV) at 50 s-1 and 300s-1, and textural properties (maximum force, cohesion, and stickiness) of ten puree dishes were analyzed prior to and after OP in five healthy volunteers until ready to swallow with a rheometer (Anton Paar RheolabQC) and a texture meter (TA.XT Plus Texture Analyzer).

Results. 1) Rheology. The 10 purees showed 81.78% variability in SV at 50s-1 (875.97±128.2-4809.85±1618.21 mPa·s). SV was significantly reduced by OP in 7 (-42.71%. $p<0.05$, french omelet, zucchini omelet, stewed turkey, red lentils, noodles, and hake fish) and unaffected in 3 (-1,7%, NS, pollock fish, cauliflower and broccoli). The variability of SV in ready-to-swallow bolus was 70.32% (555.73±356.50-1872.71±944.2 mPa.s). 2) Texture. The 10 purees also showed great variability in maximum force (0.47±0.03-1.2±0.8 N), cohesiveness (0.66±0.080-82±0.03) and adhesiveness (0.74±0.21-1.1±0.23 N·s). OP significantly reduced maximum strength (7-36%) and adhesiveness (21-51%), while cohesiveness was not significantly affected.

Conclusion. All the selected purees meet the qualitative criteria for thick texture C (BDA) puree. However, they present very different viscosities (900-4800 mPa·s) and textures, when measured by the international system of units, and are affected in a very heterogeneous way by the oral process, a fact that compromises their therapeutic effect. The implementation of our TMD analysis protocol allows establishing the optimal rheological and textural values to design TMD that provide safe swallowing in patients with dysphagia and mastication disorders.

The stability of plant protein-polysaccharide emulsions: The link to their interfacial properties

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Plant proteins are widely studied for their potential for emulsion stabilization due to their surface-active properties. But plant protein stabilized emulsions are less stable under certain conditions (pH, ionic strength, and temperature) compared to dairy or animal protein stabilized emulsions, due to their different interfacial properties. Association of plant proteins with polysaccharides through non-covalent or covalent bonding can improve the ability of plant proteins to stabilize emulsions. Here, first an overview of the interfacial properties of protein-polysaccharide complexes is given and then they are linked to emulsion stability. Covalent conjugates and non-covalent complexes are introduced, and the effect of pH, ionic strength, ratio, charge density, and molecular weight on the complex formation are discussed. Then, the behavior of protein, polysaccharide, and their blends at interfaces (mostly air-water interface) are summarized. Several interfacial properties of plant protein-polysaccharide complexes at the oil-water interface are discussed, including interfacial rheology and interfacial structure. The relationship between interfacial properties of plant protein-polysaccharide complexes and emulsion stability was summarized and in general it appears that the addition of polysaccharides leads to a denser and firmer interfacial layer and increased emulsion stability against coalescence.

The impact of use level and activation on the interfacial rheological properties of NUTRAVA® Citrus Fiber at the water-oil interface

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Supporting dietary fiber intake, NUTRAVA® Citrus Fiber is a clean-label friendly ingredient produced by sustainably sourced citrus peels, a byproduct of the fruit juice industry. NUTRAVA® Citrus Fiber contains fiber, pectin and protein, which enable unique water-binding, texturizing and stabilization capabilities. Interestingly NUTRAVA® Citrus Fiber can be used as an emulsifier to stabilize oil-in-water emulsion.

One method for evaluating the ability to stabilize oil-in-water emulsion is looking at the interface between oil and water. The interfacial rheology data reveals that NUTRAVA® Citrus Fiber stabilizes water-oil interface through providing structure at the interface. It is shown that the structure level is highly dependent on the level of activation of the NUTRAVA® Citrus Fiber - the more activated it is, the more structure evolves at the interface, whereas the use level of NUTRAVA® Citrus Fiber has minor impact on the structure at the interface. When looking at the bulk rheological properties, both use level and activation level impact the rheological properties.

Tribological model system testing of cocoa mass samples with different particle size distributions

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Particle size reduction is one of the key operations in confectionery production such as for cocoa mass wet grinding. Due to the reduction of particle size, the structure of the respective product is changed, e.g. by the release of free fat, changes in particle size distributions or changes to the surfaces of the dispersed particles. Such changes to the food structure are affecting the mouthfeel of food during oral intake. Tribological model system testing has become one of the most relevant methods in instrumented and quantitative testing besides rheology and texture analysis. In tribological model system testing, tribosystems from the real world such as tooth-tooth or tongue-palate tribocontacts, lubricated with the bolus, are studied in order to gain insights into tribology-mouthfeel-interrelationships.

Here, a comprehensive approach including structural insights to the cocoa mass samples and how they behave in the model tribosystem is presented. Cocoa mass samples were obtained by wet grinding on a horizontal ball mill using one batch of cocoa mass in order to ensure all samples possess the same composition. Sample structure was investigated via light microscopy, laser diffraction particle size analysis and rotational rheometry. Results from the tribological characterization are presented in the form of Stribeck and extended Stribeck curves. The observed differences in the frictional behavior with respect to both the static and kinetic regime of friction are discussed. Possible lubrication mechanisms are also discussed in order to enable a deeper understanding as to how the structure of cocoa mass affects the tribological behavior of the model system.

Rheological characterization of bigels and hydrogels prepared with a natural fibre

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The use of natural ingredients for the development of new food products has been a demand by consumers over the last years. In this work, a natural fibre was used to produce a hydrogel that was then used in developing a bigel foreseeing their use in water and oil-based products. The hydrogel was prepared using distilled water and the apple fibre Herbacel® AQ® AFB 200. The fibre at 5 different concentrations (1 % to 5 % (w/w)) was mixed at room temperature (22 ºC), with distilled water, under magnetic stirring and their solubilization was performed overnight. The oleogel was prepared using sunflower oil, vegetable protein and the selected structuring agents (a mixture of phytosterols and glycerol monostearate). The ingredients were mixed at 80 ºC using a mechanical mixer (operated at 2000 rpm for 10 minutes). After a 24 h stabilization period at room temperature (22 ºC) of each gel, the bigels were prepared by mixing the fibre hydrogels (90 % (w/w)) and the oleogel (10 % (w/w)) using the mechanical mixer at 60 ºC under 500 rpm during 10 minutes. After that, all formulations were left at room temperature (22 ºC) for 24 h to promote gel formation. After 24 hours, the influence of different concentrations of the apple fibre on the gelation capacity of the bigels was evaluated through a qualitative method (tube inversion), followed by a thermal, microstructural and rheological characterization.

Formulations containing 2 %, 3 %, 4 % and 5 % of fibre concentrations showed a gelled state when the results were visually observed, however, the rheological characteristics indicated that all the tested concentrations of fibre, demonstrated a solid-like behaviour (G'>G'') under the oscillatory rheometry tests. Also, the same concentrations of the bigels showed a gelled state under the tube inversion method and exhibited a solid-like behaviour, where the 5 % of fibre concentration was revealed to be stronger while reaching a G* value of 8692.4 Pa at 1 Hz.

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Thermal, rheological and physicochemical properties of oleogel-based emulsion containing peanut sprout oil

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The germination process is widely employed to enhance nutritional and medicinal values of edible seeds since complex biochemical changes occur during hydration and sprouting. The sprout is generally known to be rich in phytochemicals, proteins, vitamins, and minerals essential for human health. A few studies have reported that wide varieties of phenolic substances such as resveratrol have been found in peanut sprout, and various biological activities and physicochemical properties of peanut sprout oil (PSO) have recently begun to study for using food materials. Oleogel systems have emerged as alternatives to conventional fats with high levels of trans-fatty acids and saturated fatty acids. Moreover, the oleogelation within water-in-oil (W/O) emulsions has also been of great interest to researchers, since the fabrication of oleogel-based emulsions has shown promising applications in substituting solid fat and formulating soft spreadable products. Therefore, this study was aimed to prepare the oleogel-based emulsions containing PSO with different levels of gelators (candelilla wax and SMS) and to investigate their physicochemical, rheological, and thermal properties to utilize peanut sprout oil as a sold fat substitute in processed foods. PSO had higher phospholipid content, resveratrol content, antioxidant activity (DPPH), and oxidative stability compared to peanut oil. The textural properties (firmness and work of shear) of PSO oleogel- based emulsions were increased with increasing gelator concentration (3 and 6%), and with decreasing the SMS concentration at the same gelator concentration. PSO oleogel-based emulsions exhibited frequency-dependent viscoelastic properties as weak elastic gels which had a higher storage modulus than their loss modulus. PSO oleogel-based emulsions also exhibited temperature-dependent solid fat contents. Thus, this study suggests a new processing direction for PSO by confirming the physicochemical, rheological, and thermal characteristics of the oleogel-based emulsions.

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Production of edible insect oil-oleogels on candelilla wax and application as an animal fat replacer in meat patty

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Edible insects are attracting attention as alternative foods because of their excellent production efficiency, low carbon consumption, and high protein content. Tenebrio Molitor larvae (TM), one of the edible insects, has been worldwide consumed in various nations. Even though TM oil contains over 30% fat composed of 70% unsaturated fatty acids, most research has been focused on protein material, and there are few studies conducted on using TM oil. In order to expand the use of edible insect oil, the TM oil was structured with different ratios of candelilla wax. Oleogelation can be considered as emerging technique to transform liquid oil into a solid-like gel with a three-dimensional network without changing its unsaturated fat-rich composition. Thus, the purpose of this study was to investigate the physicochemical properties of TM oil-oleogel prepared with the different ratios of candelilla wax and to evaluate the feasibility of TM oleogels as a replacement for animal fat to reduce the level of saturated fat in meat patties. The textural properties (hardness) of TM oleogels were lower than those of beef tallow and the TM oleogels exhibited frequency-independent viscoelastic properties as weak elastic gels. The TM oleogels also exhibited temperature-dependent solid fat contents. The melting temperature of oleogels was increased with increasing gelator concentrations. When beef tallow was substituted with TM oleogels in meat patties, the cooking loss and firmness were lowered. In addition, the replacement of beef tallow with TM oleogels was significantly reduced from 66% to 47% in the levels of saturated fatty acids in the meat patties. Thus, this study can encourage the food industry to extend the application of TM oleogels to various food products.

Influence of nanocellulose with different particle size on pasting and rheological properties of maize starch and waxy-maize starch

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Tailored design of novel materials requires a deep understanding of structural properties and how structures define functionality. Cellulose nanofibrils (CNF) and cellulose nanocrystals (CNC) have been described as nanomaterials with wide applications in polymer science. However, their use in food science and nutrition, specifically in the design of food structures, is still scarce. The aim of this work was to investigate how CNF and CNC modify macrostructural properties of maize starch and waxy maize starch, such as pasting and rheological properties. Starches (Sigma-Aldrich, Germany) with different amylose content were used: maize starch (25% amylose) and waxy maize starch (0% amylose). CNF (Vuelo Pharma, Brazil) and CNC (UPC-UMaine, USA) were purchased. Starch suspensions containing CNF and CNC at concentrations up to 6% w/w were prepared. Starch-CNF and starch-CNC blends were processed by Rapid-Visco-Analysis (RVA 4500, Perten) held at 90°C for 3 min and cooled to 25°C. Pasting parameters such as pasting temperature, peak viscosity, hold viscosity and final viscosity were evaluated. After RVA, starch-nanocellulose pastes were characterized by rheology at 25°C using a dynamic frequency sweep (0.1-600rad/s, 0.05% strain) and a dynamic time sweep (4h).

CNF and CNC were first characterized in terms of size and charge, resulting in an aspect ratio of 200 and 12 for CNF and CNC respectively. The z-potential was -49mV for CNC and 1.3mV for CNF. Nanocellulose significantly modified the pasting properties, but was strongly influenced by particle size. CNF significantly increased all pasting parameters of maize and waxy pastes, whereas CNC only slightly increased the same parameters (e.g. final viscosity 1280cP, 1350cP and 3200cP in control, 6% CNC-maize and 6% CNF-maize, respectively). Rheological characterization showed that CNC and CNF produced a significant increase in G', which was also proportional to the nanocellulose concentration. However, the values of loss factor (G''/G') indicate large structural differences, which are influenced by the particle size of nanocellulose, but also by the amylose content of starch. Thus, in waxy the presence of CNC or CNF did not modify the value of loss factor, but in maize the presence of nanocellulose increased the value of loss factor, suggesting a less organized structure. The latter was confirmed by dynamic time sweep, which showed that CNC and CNF would not promote self-association of amylose during long-range retrogradation. In maize, CNC rapidly increased G', but after four hours G' values were lower than control. On the other hand, CNF showed lower G' than control over the whole-time range tested. In waxy, both CNC and CNF significantly increased G'. Regarding loss factor, our results showed that in waxy the presence of CNC and CNF did not change the values of loss factor during the time sweep test, behaving gels as weak gels over the whole-time range tested. However, in maize, presence of nanocellulose weakened the gel structure, as the values of the loss factor were higher than 0.1 over the whole-time tested (around 0.07 in maize and around 0.1 in waxy). This characterization will be complemented with data got from FTIR and x-ray diffraction analysis.

Functional food protein hydrogels generated via biocatalysis

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High-quality gelatin hydrogels contain a high level of protein α-chains, which contribute to superior gel strength and physicochemical properties, and thus have broad applications in food, pharmaceuticals, biomaterials, and biomedicine. Despite their significance, the production of α-chain gelatin has not been well studied. We hypothesized that optimized alcalase enzyme-assisted hydrolysis of collagen could achieve a precise production of α-chain gelatin. We investigated the biocatalysis of α-chain gelatin hydrogels from fish skin and examined the integrity and functionality of hydrogels when subjected to thermal treatments. Transglutaminase (TGase) enzyme catalyzes the formation of cross-linkages between Gln and Lys residues in proteins, thereby enhancing their rheological properties. Commercially available TGase exhibits limitations in modifying proteins for use in foods and pharmaceuticals at versatile conditions such as low-temperature processing. Thus, we studied the discovery, enzymological properties, structural features, and recombinant expression of a psychrophilic TGase. Protein hydrogels generated by TGase catalysis have improved texture, rheology, microstructure, thermal stability, and sensory characteristics. For example, gelatin solution sets into elastic gels upon cooling below 35 °C, and the gel network predominantly relies on hydrogen bonds. TGase can introduce additional covalent bonds to reinforce the gelation. Thus, we further used the newly discovered TGase to generate cross-linked hydrogels using peptides and gelatins, aiming to improve the antioxidant activity of hydrogels.

This study successfully produced gelatin high in α-chain by biocatalysis of alcalase enzyme under mild reaction conditions. The functional properties data suggested that the gelatin hydrogels could withstand thermal treatments, thus can suit various applications. New TGase enzyme was purified from Antarctic krill exhibited optimal activity at pH 8.0–9.0 and 0–10°C. High activity at cold temperatures enabled the use in low-temperature protein modifications. Antioxidant peptides were incorporated into gelatin to form hydrogels using recombinant TGase at 4 ◦C showed more stable bioactivity over a 10-day storage.

1. Zhang, Y., Dutilleul, P., Orsat, V., & Simpson, B. K. (2018). Alcalase assisted production of novel high alpha-chain gelatin and the functional stability of its hydrogel as influenced by thermal treatment. International journal of biological macromolecules, 118, 2278-2286.
2. Zhang, Y., He, S., & Simpson, B. K. (2017). A cold active transglutaminase from Antarctic krill (Euphausia superba): Purification, characterization and application in the modification of cold-set gelatin gel. Food chemistry, 232, 155-162.
3. Zhang, Y., Li, C., Geary, T., Jardim, A., He, S., & Simpson, B. K. (2022). Cold setting of gelatin–antioxidant peptides composite hydrogels using a new psychrophilic recombinant transglutaminase (rTGase). Food Hydrocolloids, 122, 107116.
4. Liu, Y., Weng, R., Wang, W., Wei, X., Li, J., Chen, X., ... & Li, Y. (2020). Tunable physical and mechanical properties of gelatin hydrogel after transglutaminase crosslinking on two gelatin types. International journal of biological macromolecules, 162, 405-413.

Multi Speckle-diffusing wave-spectroscopy – A powerful tool for milk gel characterization

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Dairy products are part of nutrition around the world, proposing a source of proteins, calcium and, of course, tastiness. Although milk gel preparation for cheese and yogurt is an ancestral process, research on new ingredients, such as proteins, starters and rennet is an ongoing field in food industry. The number of new ingredients and recipes is continuously increasing, asking for a fast and efficient characterization method. Passive microrheology has become of outmost interest due to its non-invasive character and easiness of use.

This work will present the principles of Multi-Speckles Diffusing Wave Spectroscopy (DWS)1. Briefly, MS-DWS consists of sending a coherent laser beam into the sample and is multiple scattered by the protein and fat particles. The interfering backscattering waves form an interference pattern (speckle image), which is detected by a multi-pixel detector. The scatterers' motion is directly related to the spot movement of the speckle image and can be analysed in the dynamic mode. The determination of the Mean Square Displacement (MSD) curve enables to characterize completely the viscoelastic properties of the sample. The second part of the work will focus on milk gels, such as used in cheese preparation. It will be shown in several examples how passive microrheology can be used for the characterization of milk coagulation. Parameters such as flocculation time, gelation time and coagulation times can be obtained and help to improve cheese recipes. Moreover, the instrument can be used for the optimization of yogurt and cheese recipes, for example by correlating the microrheological data with the texture properties, such as creaminess, ropiness and brittleness.

1. Weitz, D. A.; Pine, D. J. Diffusing-Wave Spectroscopy. In Dynamic light scattering; Oxford University Press: New York, 1993; p 652.
2. Chambon, F.; Winter, H. H. Linear Viscoelasticity at the Gel Point of a Crosslinking PDMS with Imbalanced Stoichiometry. Journal of Rheology 1987, 31 (8), 683–697.
3. Adolf, D.; Martin, J. E. Time-Cure Superposition during Crosslinking. Macromolecules 1990, 23 (15), 3700–3704.
4. Larsen, T. H.; Furst, E. M. Microrheology of the Liquid-Solid Transition during Gelation. Phys. Rev. Lett. 2008, 100 (14), 146001.

Understanding the Mechanism of Cold Gel Formation in Highly Concentrated-Micellar Casein Concentrate (HC-MCC) Solutions: Impact of Calcium Chelation and pH Adjustment

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Highly Concentrated – Micellar Casein Concentrate (HC-MCC) is a dairy product obtained by microfiltration of skim milk and vacuum evaporation resulting in 17-23% casein. When HC-MCC is held at cold temperatures (<10oC), gelation of the product is observed which could possibly be attributed to jamming effect due to closed packing of casein micelles [1] or calcium mediated protein-protein interactions. However, the exact mechanism of cold gel formation is not yet very clear. Trisodium citrate (TSC) can chelate colloidal calcium phosphate, leading to conformational changes in the casein micellar structure. This study aims at elucidating the mechanism behind the gelation of HC-MCC, whether it was due to jamming transition or structural changes in the micelle due to calcium chelation by using 0, 10, 25, 50 mM TSC or alkaline pH adjustment (6.6, 6.8, 7.0) using NaOH. Multiwave oscillatory rheology in combination with time and temperature sweeps were used to study rheological changes in HC-MCC [2]. Critical sol-gel transition point was determined using Winter and Chambon criteria, as the temperature at which the value of the loss tangent was independent of the frequency. Transmission electron microscopy (TEM) was conducted to observe ultrastructural changes in micellar structure due to sample modification. Rheological data shows that all modifications significantly increased ($P<0.05$) storage modulus (G') values from 3.6 kPa to 26 kPa and gelation temperatures (Tg) from 11.7oC to 30.2oC. Alkalization of HC-MCC from pH 6.6 to 7.0 produced stronger gels (G'=26 kPa) than chelation by using TSC at 25 mM (G'=13.1 kPa). However, both treatments (pH 7.0 and TSC 25 mM) increased Tg values to the same level i.e. from 11.7 to 29.9oC. Increasing TSC concentration to 50mM resulted in a significant decrease ($P<0.05$) in G' (8.10 kPa) and Tg (24.4oC) compared to 25mM samples. TEM micrographs confirm the existence of intact casein micelles within solution for control samples, along with minimal space between structures. TEM micrographs show that with increasing TSC content up to 25mM or increasing pH up to 7.0, disintegration of micellar structure and release of individual casein fractions was observed with concomitant increase in the gel strength suggesting that altered casein-water interactions were taking place. This can be attributed to reduced hydrophobic interactions between casein submicelles and solubilization of colloidal calcium phosphate from micellar structure at low temperature [3]. However, at 50mM TSC levels, complete disappearance of the casein micellar structure and the formation of larger casein aggregates with decreases in gel strength was observed. This study shows the potential of forming thermo-reversible cold gels through physio-chemical modification of HC-MCC.

[1] Lu et al.: J Dairy Sci. (2015) doi https://doi.org/10.3168/jds.2015-9482
[2] Zad Bagher Seighalani et al.: Food Hydrocolloids (2021)
doi https://doi.org/10.1016/j.foodhyd.2021.106886
[3] Horne, D. S.: Current Opinion in Colloid & Interface Science (2006)
doi https://doi.org/10.1016/j.cocis.2005.11.004

Multiscale imaging of structure formation during high-moisture extrusion processing of soy proteins

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There is a growing concern about the negative impact the production meat has on the environment. In recent years, the food industry has invested in developing plant protein-based meat alternatives, but one major obstacle in creating appealing products for consumers is the inherent lack of fibrous structure. High-moisture extrusion is a proven industrial technique used to create structured plant protein materials, involving the mixing and hydration of protein, followed by thermomechanical treatment and subsequent cooling under shear in a cooling die. However, the process mechanisms influencing the final texture of the extrudate are not fully understood. Here, we study structure formation in soy protein extrudates during passage of the cooling die through the use of dead-stop experiments. We depart from the hypothesis that the temperature gradient applied to the material in the cooling die induces concurring phase separation and alteration of the viscosity of the protein melt in a spatially dependent manner. Building on the work by Wittek et al. 2021 [1], magnetic resonance imaging (MRI) is here utilised to non-invasively investigate the macrostructure at the mm-cm length-scale, of the phase-separated protein domains in soy protein extrudates as a function of extruder barrel temperature, moisture content and residence time in the cooling die. Additionally, confocal laser scanning microscopy (CLSM) is used to investigate the underlying microstructure at the µm-mm length-scale. MRI images clearly show a spatial dependent lamellar phase separation in protein-rich and protein-poor phases. Coarse lamellar aligned exterior regions are discernible from less structured interior regions of the extrudate, and their relative volume increases across the length of the cooling die. CLSM imaging unravels how the underlying microstructure varies in alignment of carbohydrate fibres and protein fibrils. The alignment Fourier transform method by Marcotti et al. (2021) [2] is used to quantify the shape and orientation of the laminar flow pattern and protein fibril bundles, providing a starting point for understanding the complex rheological behaviour of these protein melts during extrusion.

[1] P. Wittek, et al. Foods 2021, 10:7, 1509.
[2] S. Marcotti et al. Front. Comput. Sci. 2021, 3, 745831

A viscoelastic rheological model to predict the small-scale structure of meat alternatives produced using high moisture protein extrusion

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When consuming plant protein-based products, the texture provides a significant contribution to the eating and tasting experiences. The quality of these products is closely linked to both the rheological properties of the protein dough when processed in a high moisture protein extruder (HME). HME is an important manufacturing process for meat alternatives and a large amount of commercially available products use this technique. Thus, it is crucial to understand the link between the rheological properties and the resulting structure. Knowing this relationship will allow us to make predictions about the extrudate structure and help accelerate hypothesis-driven research by predicting interesting experimental parameters. This relation would be captured in a rheological model. The model would aim to describe the permanent deformations the meat analog contains after it has been processed; seen as protein fibril alignment at a (sub-) μm scale and a multiphase structure at the mm-cm scale, which together with other phenomena make up the total deformation. To achieve this, we will approach the material as an elastoviscoplastic (EVP) material, which undergoes both elastic and viscous deformation. As proteins in meat alternatives align in shear flow, we aim to describe their microstructural development with a configurational tensor, which will be an integral part of the rheological constitutive model. This tensor indicates the degree of anisotropy and its direction. The changes in this tensor are both governed by the flow as well as the energy put into the system by temperature and shear stresses. Without taking the microstructure into account the protein melt inside the HME can be described as Herschel-Bulkley fluids. With the configuration tensor undergoing viscoelastic relaxation, we extend the Herschel-Bulkley model towards an EVP model. The model will be tested with large strain sweeps at different frequencies, temperatures (>100oC), and moisture contents (54-63%). We will probe for scaling rules, as in our previous study(van der Sman et al., 2022), in the form of function T/Tg: the ratio of actual temperature and (moisture-dependent) glass transition temperature.

Structure formation and structure evolution during high moisture extrusion of soy proteins studied by scattering techniques

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Due to health and environmental factors, the food industry is looking for ways to introduce meat alternatives made from plant-based proteins to consumer markets. High-moisture extrusion (HME) is the most widely used method for converting proteins and polysaccharides into a meat alternative with a highly hierarchical fibrous structural organization. However, the HME process is usually considered as a "black box" with limited information about structure formation inside. The dead-stop operation is a feasible and effective method to collect material from different extruder and cooling die zones. In this study, scattering techniques were applied to study the evolution of meat analogue structure by sampling material after a dead-stop. By combining wide-, small-, and ultra-small-angle scattering methods, we have probed the structures of meat alternatives from the nano- to the micrometre range and established relationships between them. We have demonstrated that anisotropic structures were present already in the transition zone of the extruder and they developed further along the entire cooling die section. It also appeared that these anisotropic structures were formed at length scales of a few tens of nanometres with an increase of anisotropy at larger length scales. These findings represent a starting point in the understanding of the mechanisms of structure formation and evolution in the extruder and cooling die at several hierarchical levels.

Structural, textural and quality characteristics of slices of carrot dehydrated using different methods

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The global market for healthy snacks has increased in recent years, finding a variety of dehydrated vegetable-based products such as sweet potatoes, pumpkins, carrots, kales, and broccolis which are used for cooking or consumed as snacks. Carrot is a widely spread vegetable that is consumed mainly fresh, and also as snack, or in culinary preparations of the dehydrated and reconstituted product. This vegetable has a significant content of antioxidants provided mainly by β-carotene and phenolic compounds, which makes it in an excellent candidate for the obtention of healthy snacks. The goal of this work was the obtention and the study of the structure, texture and quality characteristics of carrot snacks, applying different methods to carrot slices: a) convective hot air drying at 60 and 80oC (CD), b) microwave as a previous step to hot air drying (MWCD) and c) freeze drying (FD) (process used as control). Drying kinetics indicated a reduction in time of more than 50% for MWCD respect to CD. The freeze drying was the longest process. Structural studies carried out by TEM, revealed that the cellular membrane was preserved in F, while in MWCD the cells were more separated and the cellular membrane totally altered. The dried matrix obtained after CD, showed a more compact structure with the cellular membrane partially destroyed. Measurements of the shrinkage showed that the CD process produces the highest value and the FD process the lowest. MWCD sample showed the intermediate value. The rehydration measurements, that are related to the structure, indicated that the MWCD sample absorbed more water than CD sample and the FD sample the highest. The crispness of the snacks was determined as the maximum force (fmax) of a three-point bending test. The crispiest sample, with the lowest fmax, was the one obtained by the MWCD among the methods that applied heat. No difference in shrinkage, rehydration and crispness were observed with the different drying temperatures. There were found no differences in the antioxidant capacity among the samples obtained by the different methods. These results show that the use of microwave as a previous step of dehydration with hot air reduced the processing time and resulted in a more porous dehydrated matrix due to the puffing effect of the microwaves, preserving the antioxidant capacity with good texture properties.

Potato flour as functional component in foods. A Physicochemical, rheological and structural study

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Potato is the main food crop after rice and wheat and an important source of carbohydrate (starch), protein of good quality, vitamin C and minerals. The more relevant studies in the literature have been focused on starch, and there are few studies about flours, which have a better nutritional composition. Since the starch is the major component of the dry matter of potatoes, it is expected that the functional properties of flours are dependent on it. In this work, potato flours were obtained by freeze and thawing process and then drying at 60oC potato slices, grinding and saving. The flour studied was the fraction that passed a sieve of 105mm. Starch was extracted from fresh potato tubers and was used as control. In all cases, citric acid and sodium bisulfite were used to preserve the samples from the enzymatical browning (antibrowning agents) and compare with a process without this treatment. The amylose: amylopectin ratio of the starch was measured an the result was 28:72 (w:w). Structural studies of flours carried out using optical microscopy and SEM, showed the presence of particles, irregular in shape, compared to the starch where the typical potato granules were observed. Chemical composition indicated that flours exhibited higher protein, ashes, lipids and fiber contents than the starches and a 77% of starch content on dry basis. No difference in the whiteness index between the flour obtained in presence of antibrowning agents and the starch was obtained. Differences in thermal, flow and dynamical rheological properties were found in gelatinized systems of flour and starch at 5 and 10% (w/w). These results indicated that the potato flour exhibited similar functional properties to the starches.

Calcium ion induced changes in rheological and textural properties of potato starch gels and potato mashes

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Potato-based mashes are used industrially in a range of (pre-)fried frozen potato products. It is important that they have a consistent quality, as their rheological and textural properties impact shape retention and product integrity during deep-frying. Here, we explored the use of mineral ions to control the mash properties. Ca^{2+}-ions impact the properties of the main constituent of potato mashes, potato starch (PS), by establishing ionic bridges between the phosphate groups of PS amylopectin. We examined the effect of $CaCl_2$ addition on the textural and rheological properties of both PS gels and potato mashes.

First, we evaluated how $CaCl_2$ addition alters the PS gel properties [16% dry matter (dm); 0-10 µmol $CaCl_2$/g PS dm)] by Texture Profile Analysis and oscillatory shear rheology measurements. Next, we evaluated the impact of $CaCl_2$ on the properties of mashes prepared from raw potato tissue of the cultivar Fontane. To that end, the potato tissue was blanched in water with or without $CaCl_2$ (0-25 µmol $CaCl_2$/g potato dm), steam cooked and mashed. The texture, viscoelastic properties and proton mobility [analyzed with Low field Proton Nuclear Magnetic Resonance (LF-1H- NMR)] of potato mashes were studied. Oscillatory shear rheological measurements revealed that $CaCl_2$ addition caused the storage and loss moduli (G' and G") to decrease by ca. 45% when 10 µmol $CaCl_2$/g starch dm was used for PS gel making or when 25 µmol $CaCl_2$/g potato dm was added to the blanching water used for producing potato mashes. This observation was unexpected based on the above mentioned ionic bridges brought about by Ca^{2+}-ions. When 25% compression was applied during Texture Profile Analysis, increasing dosages of $CaCl_2$ gradually decreased the hardness by up to 66% for PS gels and 32% for potato mashes at the above mentioned highest dosages, which was in line with the rheology results. LF-1H-NMR showed that $CaCl_2$ addition lowered the mobility of protons in the starch gel network in potato mashes by evaluation of the T_2 relaxation time of water protons that exchange with starch hydroxyl protons, indicating an increased interaction between starch and water. The use of $CaCl_2$ decreases the viscoelastic moduli and hardness of PS gels and potato mashes by affecting the network formed during PS gelling. At the above cited $CaCl_2$ dosages, the hardness of potato mashes was less impacted than that of PS gels. This indicates that other mechanisms in potato mashes also contribute to their firmness. The outcome of this work can be used by manufacturers to tailor and control the product quality.

Effect of freeze-concentrated glass transition on the rheological properties of ice cream

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Ice cream is a well-known and popular frozen dessert. For the quality control of ice cream, the quantity and size of fat globule, ice crystal, and air cell have been commonly considered. In the contrast, there is little consideration of the physical property of freeze-concentrated phase. Freeze-concentrated phase is composed mainly of water-soluble carbohydrate mixture (sucrose as an ingredient and lactose originated from milk) and hydrate (unfrozen) water. The viscosity of freeze-concentrated phase increases with a decrease in temperature, and freeze-concentrated glass transition occurs at the freeze-concentrated glass transition temperature (Tg'). It is expected that Tg' of ice cream is affected by the types of water-soluble carbohydrate, and the Tg' will be useful for the texture indicator of ice cream; the higher Tg', the higher viscosity (thus harder texture) at a given temperature. In this study, ice cream samples were prepared using various types of carbohydrate including sugar alcohol, and effect of Tg' on the rheological properties of ice cream was investigated.

Ice cream sample was prepared from fresh cream, milk, egg yolk, and carbohydrates; sucrose, sorbitol, dextrin, sucrose-sorbitol mixture (40% sorbitol), sucrose-dextrin mixture (40% dextrin). Milk and cream were heated up to 60 ºC and then the other ingredients were added into there. The mixture was quenched and aged at 4 ºC for 24 h. The ice cream was prepared using an ice cream maker, and then stored at -30 ºC. The sample was held at -18 ºC for 18 h before measurements. Overrun of the ice cream was determined from the mass per volume. Tg' was determined using a differential scanning calorimetry (DSC). The rheological properties (storage modulus, G' and loss modulus, G") were evaluated at -15 ºC, -10 ºC, -5 ºC, and 0 ºC using a dynamic mechanical thermal analysis (DMTA). DSC curve of ice cream samples showed two endothermic shifts suggesting freeze-concentrated glass transition as similar to the carbohydrate aqueous solutions, and Tg' values were determined from their onset point. The Tg' values of ice cream increased in the order dextrin, sucrose-dextrin, sucrose, sorbitol-sucrose, and sorbitol. The Tg' values of ice cream corresponded to those of each carbohydrate aqueous solution used for the ice cream. The G' and G" of ice cream samples tended to increase with increase in the Tg' at each temperature except for 0 ºC. Since the viscosity of freeze-concentrated phase increases with increase in the Tg' of ice cream, the harder texture will have been generated. In addition, overrun of ice cream tended to increase with the increase in Tg'. Air cell will have been stabilized physically by the harder freeze-concentrated phase. From these results, it was found that the texture of ice cream was affected by the freeze-concentrated glass transition.

Effects of the starch gelatinization and rheological properties of dough on the expansion of steamed cake made from rice flour

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In recent years, rice flour has attracted attention as an alternative material to wheat flour because of the increasing number of wheat-allergic patients. However, rice flour has much lower extensibility than wheat flour because of the lack of gluten. In the case of a steamed cake made with rice flour, structural shrinkage tends to occur readily. In order to improve the quality of steamed cake made from rice flour, the effects of starch gelatinization and the rheological property of the dough on the expansion of steamed cake made from rice flour were investigated.

For the preparation of dough, firstly, whole egg, water, and sucrose were mixed at various weight ratios and whipped. Secondly, rice flour and baking powder were sifted into the previously prepared ingredients and mixed. Finally, canola oil was added to the mixture and gently mixed. The dough sample was placed into a cup, steamed for 10 min, and cooled at ambient temperature for 1 h. The apparent volume of steamed cake samples was evaluated using a 3D scanner, and the expansion index (volume after steaming per volume before steaming) was calculated. Starch gelatinization temperature in the dough was evaluated using differential scanning calorimetry (DSC). Storage modulus (G') and loss modulus (G") of the dough were investigated in the temperature range between 25 ºC and 100 ºC using a dynamic mechanical thermal analysis (DMTA). To eliminate the influence of the air bubbles, the baking powder was not added to the dough in DSC and DMTA studies.

Starch gelatinization temperature increased from 68 ºC to 101 ºC with a decrease in the water content of the dough. The sample of which starch gelatinized at 101 ºC showed a comparatively poor appearance as a steamed cake due to incomplete starch gelatinization since the temperature of the saturated water vapor during steaming was only 100 ºC. Among the other samples, there was a linear relationship between the apparent volume of steamed cake and the starch gelatinization temperature of the dough, and the expansion index tended to increase with an increase in the starch gelatinization temperature of the dough. In addition, the expansion index tended to increase with a decrease in the G' at approximately 100 ºC. From these results, it is suggested that structural shrinkage of the steamed cake made from rice flour occurs when gelatinized starch is hydrated with a larger amount of water because the steamed cake matrix becomes pasty. Taking this suggestion into account, the water content of the dough should be controlled to keep the starch gelatinization temperature below 100 ºC. When the steamed cake made from rice flour was prepared accordingly, the largest expansion index could be observed among the steamed rice cake samples.

Textural and microstructural properties of thawed pork by tumbling under vacuum

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Pork is one of the most widely consumed meats around the world. It is mainly stored in a frozen state after slaughter and undergoes a thawing process before processing. The thawing process greatly affects the quality characteristics of raw pork meat and processed products. In this study, vacuum tumbling conditions for thawing frozen pork were optimized and changes in quality characteristics related with texture and microstructure of thawed pork were investigated. Frozen pork was thawed in a 100 L-scale tumbler under vacuum, which was designed according to BBD (Box-Behnken Design) among response surface methodology. Vacuum (-35, -55, and -75 kPa), temperature (20, 30, and 40℃), and rotational speed of tumbler (1, 2, and 3 rpm) were set as independent variables that could affect the quality of frozen pork after thawing, where color, drip loss, water holding capacity, cooking loss, textural property and microstructure of thawed pork were set as dependent variables related to quality characteristics. Quality characteristics of thawed pork were significantly affected by the thawing conditions, especially in terms of drip loss, water holding capacity, cooking loss, hardness and chewiness. Overall, as vacuum level (kPa) increases and temperature decreases, drip loss and cooking loss of pork decreased. Increased in cooking loss caused the increase in hardness and chewiness of both thawed and cooked pork. The optimal thawing conditions for frozen pork were confirmed to be at a vacuum of -66.07 kPa, temperature of 20.69℃ and rotation speed of 1.68 rpm, based on drip loss, water holding capacity and cooking loss of thawed pork (total 15 trials according to BBD). The cooking loss of pork thawed under optimal condition was significantly lower (at 0.29%) compared to the pork thawed under air (0.38%) ($p<0.05$). On the other hand, the hardness of pork thawed under air was about 5 times higher (212.03 N) than that of cooked pork (46.03 N) after thawing under the optimal condition. This indicates that the moisture content which can be retained in pork varies depending on the thawing conditions, which can greatly affect the texture of cooked pork during mastication.

The impact of fermented rye and barley scald on structure formation and physical properties of wholegrain dough and bread

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The structure of wholegrain rye and barley bread represents a complex mixture of starch and non-starch polysaccharides along with proteins and lipids. The presence of an extensive amount of dietary fiber adversely affects the structure-forming process during bread making. In addition, arabinoxylans in the rye and b-glucans in barley demonstrate high water binding capacity and the ability to form viscous solutions. Considering these aspects, wholegrain flour's bread production is complicated.

Using scalding and fermentation technology in the preparation of wholegrain bread contributes to the achievement of acceptable structural characteristics of dough and crumb and benefits the bread-making process, reducing staling rate.

Scalding is the technological process when hot water (96-98 °C) is poured over the flour to prepare scald. This process makes starch more accessible to α- and β-amylases by activating the chemical reaction called starch gelatinization. Under the action of amylolytic enzymes, dextrins and other fermentable sugars are formed that are preferable for lactic acid bacteria (LAB) than starch itself. Therefore, scalded flour can be considered a substrate for thermophilic LAB, such as Lactobacillus delbrueckii. In addition, hydrocolloids that are formed during fermentation possess thickening properties and are considered natural texture improvers.

The influence of scalding on the textural characteristics of rye and barley sourdough bread was specified in this study. Two experiments were completed to determine fermented scald and dough viscosity and textural properties. First, to analyze changes in rheological properties during fermentation, the viscosity of scald and dough was determined using a rheometer (Anton Paar, MCR 302, Austria). Texture changes were observed with a texture analyzer (TA.HD.plus, Stable Micro Systems, UK). Microstructural surface images were taken by Mira3 scanning electron microscope (Tescan Orsay Holding, a.s. Brno, Czech Republic). To evaluate the physical properties of the bread, such characteristics as hardness, porosity, volume, and crumb texture were determined.

Overall there were observed substantial changes in the structure of scalded flour and their impact on fermented dough and bread crumb compared to wholegrain sourdough bread without scald. During scald fermentation which lasted for 24 h, changes in complex viscosity of fermented rye and barley scald were revealed. The complex viscosity of fermented rye flour scald decreased, while a slight increase was observed in the fermented barley scald viscosity. Storage modulus G' was higher than loss modulus G" in fermented scald and dough, which indicates more elastic portion over viscous characteristics. Rye scald firmness showed a larger decrease after 24 h of fermentation compared to barley scald. The use of fermented scald in the bread dough preparation demonstrated a positive effect on dough handling and bread structure. Fermented rye or barley scald can be utilized as a natural bread crumb improver.

Flow properties of cocoa butter-based suspensions after ball and roller mill grinding are highly influenced by local surface properties of sucrose particles

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While cocoa particle fraction already possesses the required low particle size before added to the chocolate manufacturing process, crystal sugar particles have to be ground to sizes below 25 to 30 µm to avoid a sandy mouth feeling. With respect to further processing, grinding should also result in a molten chocolate mass, which can be considered as a cocoa butter-based or lipophilic suspension, with low yield value and low viscosity.

It is already well-known that different grinding procedures either in roller mills or in ball mills result in different flow properties of the chocolate mass despite similar particle size distributions. However, the physicochemical reasons for the different macroscopic behaviors of such lipophilic suspensions are still not completely understood, since aspects concerning local changes of solid surface states and their influence on local interactions with the lipophilic environment have not been examined in detail, yet.

Previous findings indicate that grinding in such an environment transfers sucrose surfaces from crystalline to amorphous state affecting the interaction of particles with each other and with surrounding cocoa butter. But it is still unknown, whether surfaces are completely modified or whether there is a certain distribution of crystalline and amorphous regions on the surfaces and how they change during the grinding progress.

Therefore, we used atomic force microscopy to identify local amorphous and/or crystalline surfaces at microscopic scale by measuring local softening temperatures on sucrose surfaces during grinding. These results were combined with data about water sorption behavior of sucrose particles as a global indicator for presence of amorphous structures, amount of fat immobilized on the sucrose surfaces, and flow properties.

Interestingly, we found totally different directions how the surface structures changed during the grinding progress either in ball mill or in roller mill. Our findings suggest that differences in macroscopic behavior of the lipophilic suspension are more correlated to the different directions of change in local surface structures during grinding compared to more global surface structure parameters, e.g. total portion of amorphous surfaces.

Rheological properties of Highly Concentrated- Micellar Casein Concentrate as affected by pH and temperature

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Highly concentrated micellar casein concentrate (HC-MCC) is a protein ingredient which is largely used for standardization of cheese milk and preparing high protein beverages. HC-MCC have great potential for food fortification because of its gelling ability upon cooling. Environmental factors such as pH and temperature, affect significantly structure and physical properties of MCC which can also influence product processing and designing equipment. The objective of this study was to investigate the rheological properties of MCC as affected by pH and temperature.

The pH (natural pH 6.6) of MCC (23% proteins) was adjusted to 6.3, 6.1, 5.8 by addition of glucono-delta-lactone (GDL) at different levels. Rheological measurements were performed on HC-MCC at 5, 25, 55°C for all pH levels using MCR 302 Rheometer. Frequency sweeps were carried out at a range of 1-100 rad/s to understand effect of rate of applied strain or timescale of deformation on viscoelastic properties of HC-MCC.

Temperature sweep test was conducted between 5 to 35°C at three different frequencies (0.1, 1, and 10 HZ) to determine thermal stability of natural pH MCC. Storage modulus (G') and loss modulus (G") for MCC decreased with temperature in the pH range 6.1-6.6 for both amplitude and frequency sweeps, indicating softening matrix and weakening of bonds. Lowering the pH further to 5.8 reversed the trend with higher values of G' and G" as compared to pH 6.1, and it was more noticeable at 55°C. MCC at pHs 6.6, 6.3, and 6.1 showed elastic-dominant behavior (G'>G") at 5°C, while they showed viscous-like behavior (G">G') at 25°C and 55°C. In all three frequencies (0.1, 1, 10 HZ), both G' and G" decreased as testing temperature increased during the temperature sweep test, and the temperature corresponding to G' and G" crossover significantly ($p<0.05$) changed with respect to frequency.

The finding of this study will provide useful information for food industries that use MCC as an ingredient in their products. The result could help them with product processing and equipment design to optimize the functionality and quality of the final products.

Relating pea and salivary protein interactions to salivary lubrication and astringency perception

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Mouthfeel perceptions such as astringency are governed by the properties of the food-saliva mixtures. Interactions between plant and salivary proteins are a key factor to consider the astringent perception perceived during the consumption of plant-based beverages.

Three pea protein fractions (legumin, vicilin and albumin-rich) were extracted from a commercial pea flour and their astringency levels were assessed by a trained panel.

A basal level of astringency was perceived in all the pea protein fractions, but the albumin-rich fraction was perceived as being significantly more astringent. Tribology studies evidenced a significant less of salivary lubrication with all the protein fractions which can be related to the basal level of astringency. QCM-D measurements showed that the thickness and viscoelastic properties of the protein films formed on the salivary pellicle differed depending on the fractions. The film formed by the albumin-rich fraction was significantly thicker and more rigid compared to the others, which can be related to the higher level of astringency perceived.

This study identifies albumin proteins as highly reactive proteins able to trigger protein aggregation and astringency perception. This is essential to guide the development of future plant protein-rich reformulations with optimal sensory attributes.

Velocity-profiling-based rheometry along the food value chain from production to digestion of complex fluid food

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Rheological characterization is essential for the development and optimal processing of food. Its abundant properties contribute to the rich texture and better swallowability while causing difficulty in mechanically identifying the rheological characteristics. Some examples are gel-sol coexistent fluids and suspensions containing milli-meter-sized dispersions, which are challenging to deal with in a standard torque-type rheometer. Expansion of the applicable range of the rheological measurement is our motivation, and we have been developing new rheometry coupled with ultrasonic velocity profiling in the last decade. Our progress will be reported from the following aspects: The development of in-vitro rheometry for evaluating viscoelasticity and flow curves, flow prediction based on the identified properties, and in-line rheometry for pipe flow. These aspects industrially correspond to practical implements for evaluating the functionalities of a newly developing product, optimizing its production lines based on flow prediction, and monitoring the real-time quality of the product in the plant, respectively.

Regarding the first topic, the principal is that the rheological properties are reflected in its fluid motion. Spatiotemporal velocity distribution in an oscillatory or stationarily rotating cylindrical vessel is captured by ultrasonic velocity profiling, which is named ultrasonic spinning rheometry (USR). Viscoelasticity and flow curves are inversely evaluated from the velocity information via equations of fluid motion. The local evaluation realizes high applicability to complex fluids such as bubble suspension and rice porridge. As an application example, we will introduce an evaluation of rice porridge modified with three types of polysaccharide thickeners and the time variation of their shear-thinning properties after adding alpha-amylase. Once the accurate rheological properties are obtained, they can be applied to flow prediction for designing production pipelines. The obtained flow curve of the original porridge was utilized for predicting one-dimensional laminar flow in a pipe under a steady pressure gradient, which is basic but industrially the most practical target. Experiments were conducted in a pilot pipeline to verify the accuracy of the predictions. Characteristic velocity distributions originated from the yield stress and shear-thinning properties were accurately predicted. The maximum relative error of converted flow rates was less than 10%.

Regarding the last topic for the in-line rheometry, the principle of the USR is extended to pipe geometry. Utilizing pulsatile flow induced by a rotary lobe pump, radial profiles of viscosity and shear rate are obtained, and hence real-time monitoring of shear-rate-dependent viscosity is realized. This methodology, named ultrasonic in-line rheometry (UIR), does not require pressure sensors, and UVP can be applied outside the pipe. UIR is non-invasive to fluid products flowing in the pipe, which is a preferable characteristic in food fabrication. As an application example, the time variation of shear-thinning properties of the rice porridge during the addition of water, thickener, and enzyme will be introduced. As the in-vitro and in-line rheological characterization and flow prediction do not assume a rheological model and can be applied to the porridge, these are expected to be practical tools along the food value chain in a quantitative way.

How sensory juiciness of plant-based meat analogues and beef patties relates to food and bolus properties

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This study aimed to understand juiciness and texture perception of PBMAs and beef patties by linking food and bolus properties to sensory characteristics. PBMAs and beef patties were cooked sous-vide until four core temperatures (60, 70, 80, 90°C) were reached. A rank-rating test (n = 97 for PBMAs, n = 100 for beef patties) demonstrated that with increasing core temperature the juiciness intensity decreased significantly ($p < 0.05$). Juiciness intensity correlated strongly with cooking loss and composition of cooked PBMAs and beef patties. Rate-All-That-Apply (RATA) profiling (n = 99) of PBMAs revealed that as juiciness increased, fattiness increased whereas dryness decreased. RATA profiling (n = 95) of beef patties showed that as juiciness increased, tenderness and fattiness increased, whereas dryness, hardness and chewiness decreased, indicating that the impact of juiciness on other textural sensations was stronger in beef patties than PBMAs. Food oral processing behaviours (n = 10) were not significantly influenced by juiciness of PBMAs and beef patties. Properties of expectorated bolus at the moment of swallowing (n = 10) showed significant ($p < 0.05$) but only small differences in bolus composition and saliva uptake for PBMAs and beef patties. Even though initial food properties differed between samples and affected juiciness, these differences did not lead to differences in bolus properties. This suggests that juiciness of PBMAs and beef patties is not driven by bolus properties at the moment of swallowing, but is rather perceived at early stages of mastication and consequently related to bolus properties during early stages of mastication. Juiciness perception was positively correlated to serum release during mastication which was related to instrumentally measured serum release for PBMAs. We conclude that juiciness perception is primarily determined by serum release during mastication, food composition and released serum composition rather than bolus properties at the moment of swallowing.