18th International Hydrocolloids Conference, Mar. 30-April 2, Tokyo University of Marine Science and Technology Shinigawa Campus, Tokyo, Japan

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[1008] Safe and Functional Red Algal Polysaccharide Funoran for Gut Health Applications

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Gloiopeltis furcata is a major natural source of funoran, an agaran-type sulfated galactan. The primary repeating unit of funoran, **G6S**–**LA** (β-D-galactose-6-sulfate–3,6-anhydro-α-L-galactose), underlies its distinctive structural and functional characteristics. Due to its moderate gel strength, flexibility, and high biocompatibility, funoran serves as a promising hydrocolloid for texture modification, stabilization, and incorporation into functional food systems.
Funoran was isolated through a sequential cascade extraction process, followed by partial depolymerization via controlled auto-hydrolysis. The molecular weight distribution and structural characteristics of both native and depolymerized polysaccharides were analyzed using size-exclusion chromatography (SEC), FTIR, and NMR spectroscopy. Caco-2 cell assays revealed no cytotoxic effects upon treatment with either native or depolymerized funoran. The gene and protein expression levels of tight junction markers (Claudin-1, Occludin, and ZO-1) remained comparable to the control group, indicating that epithelial barrier integrity was preserved during polymer exposure. In contrast, cells treated with dextran sulfate sodium (DSS) showed markedly reduced expression of these tight junction proteins. Cholesterol, which is essential for maintaining intestinal tight junctions, was also significantly decreased in DSS-treated cells, while its level remained unchanged in funoran-treated cells, similar to the control group. Interestingly, the partially depolymerized funoran exhibited stronger inhibition of intestinal pathogenic bacterial growth and promoted the proliferation of probiotic bacteria more effectively than the native polymer. In vivo studies in mice demonstrated that oral administration of both native and depolymerized funoran solutions caused no observable toxicity, confirming their safety for potential food and therapeutic applications. In a DSS-induced colitis mouse model, funoran—particularly the depolymerized form—effectively prevented colon shrinkage typically seen in DSS-treated mice. Similarly, spleen enlargement associated with inflammation was alleviated in DSS-treated groups, where spleen size funoran-treated groups remaining comparable to healthy controls. Moreover, the serum concentration of the pro-inflammatory cytokine TNF-α and the expression of myeloperoxidase (MPO), a marker of inflammation, were significantly reduced in funoran-treated mice compared to DSS controls. Collectively, these results suggest that sulfated polysaccharides like funoran possess notable anti-inflammatory and gut-protective properties, with molecular weight playing a crucial role in modulating immune responses in intestinal systems.

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1009 High-internal-phase Pickering emulsions stabilized by aggregates isolated from *Agaricus bisporus* wastes

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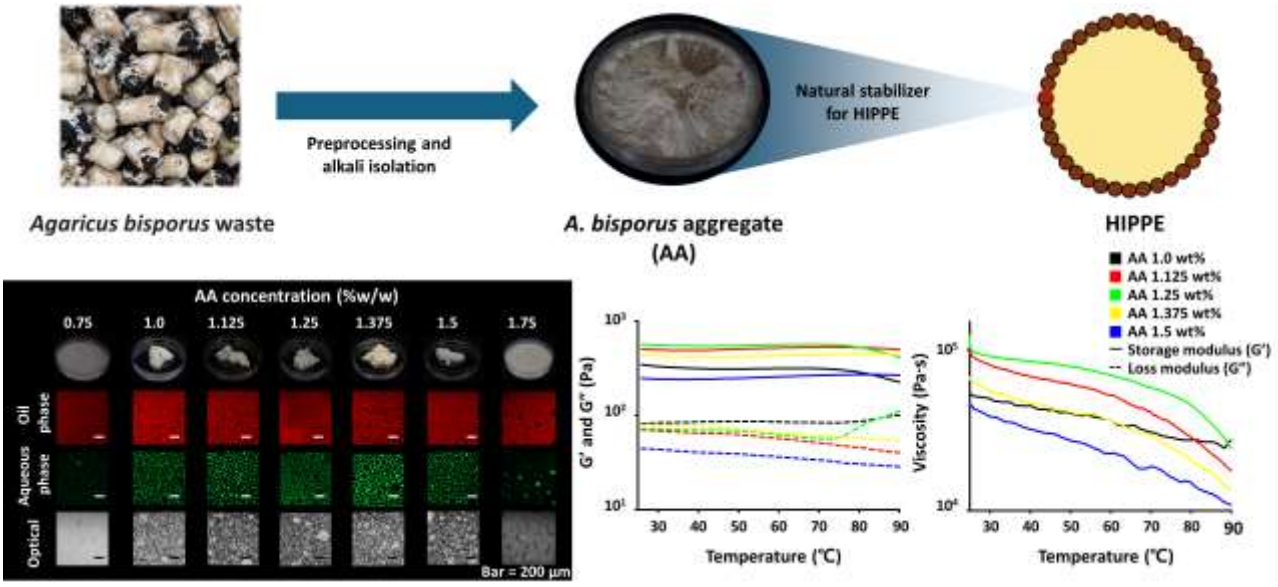
The investigation of high-internal-phase Pickering emulsions (HIPPEs) by food scientists has been motivated by their remarkable structural stability, which has significant implications for the development of innovative food textures and the delivery of lipophilic components. The development of sustainable food-grade stabilizers has proven to be a persistent challenge in the context of the HIPPE system in the food industry. In this study, *Agaricus bisporus* aggregates (AAs), derived from the wastes through preprocessing and alkali isolation, were evaluated for their potential as a natural stabilizer for HIPPEs. Stable HIPPEs were prepared with AAs in a range of 1.00–1.50%w/w. In contrast, HIPPEs were not prepared with insufficient (0.75%w/w) and excessive (1.75%w/w) AAs, resulting from incomplete and overload interfacial coverage, respectively. In the stably prepared HIPPEs, it was confirmed that the uniform size distribution of oil droplets was attributable to effective AA adsorption at the oil-water interface. Furthermore, it was observed that all stable HIPPE formulations exhibited gel-like behavior, with G′ consistently exceeding G″. It is noteworthy that the HIPPE prepared with 1.25%w/w AA exhibited the most pronounced viscoelasticity and thermal resistance (25–90°C), indicative of a robust interfacial network. These findings demonstrate the viability of AAs as a sustainable HIPPE stabilizer and provide insights into the rational design of stable food structures.



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[1010] Characterization of *Citrus unshiu* waste-isolated pectins and high-internal-phase Pickering emulsification using the

pectin aggregates with soy protein isolate

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The objective of this study was to extract and characterize pectins from diverse waste fractions of *Citrus unshiu*, which were aggregated with soy protein isolate and utilized to stabilize the oil droplets as high-internal-phase Pickering particles. All pectins extracted from flavedo, albedo, and pomace (extraction yield: 14.22, 17.56, and 14.33%, respectively) were found to be low-methoxyl with degrees of esterification of 27.40, 28.79, and 36.28%, respectively. Furthermore, all pectins exhibited shear-thinning behavior, with consistency index values of 5.13, 0.79, and 0.47 Pa·s for flavedo, albedo, and pomace, respectively. The average molecular weights were determined as 72, 29, and 7.4 kDa, respectively, based on the observed viscous behaviors. It is noteworthy that flavedo-extracted pectin demonstrated the highest dislocation density and glass-transition temperature among all the anmorphous pectins, a phenomenon that may be ascribed to its elevated calcium ion content (9.63 mg/g) and ionic interactions. The pectins were aggregated with soy protein isolate (SPI) at pH 3.5 and 4.0 through ionic and hydrogen interactions, and utilized to prepare high-internal-phase Pickering emulsions (HIPPEs). The HIPPEs that were stabilized with these aggregates demonstrated superior centrifugal and storage stabilities, with no phase separation, in comparison to those stabilized solely with either SPI or pectin. Consequently, the results suggest that pectins originating from *Citrus unshiu* waste have the potential to be used as a food additive, such as a stabilizer or emulsifier.

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[1019] Bioactivities of native and low molecular weight hybrid polysaccharide from the edible *Vertebrata lanosa*

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The bioactivities of polysaccharides isolated from the edible epiphyte *Vertebrata lanosa* and their respective low-molecular-weight (LMW) biopolymers were investigated in this study. A sequential extraction procedure was carried out on ethanol-treated and non-treated algae biomass to yield polysaccharides of a hybrid nature, containing two agaran-type polysaccharides, namely funoran and porphyran. The molecular weights of native polysaccharides ranged from 500 to 5520 kDa. Selected native samples were further subjected to ultrasonication (60–180 min) to yield LMW fractions ranging from 62 to 131 kDa. A comparative analysis between the ethanol-treated (B1) and non-treated (B2) samples revealed variations in the molecular weights of native polysaccharides with influence from the respective extraction conditions. The different antioxidant assays further showed a synergistic effect of molecular weight, sulfate, and sugar acids on the capacity of both native and depolymerized samples. A significantly high neutralization efficiency against hydroxyl radicals (up to 95%) was recorded in LMW samples. The inhibition of α-glucosidase enzyme by the tested samples was shown to be highest in the LMW polysaccharides prepared using room temperature extracted fractions. In vitro assays using selected native fractions showed no cellular toxicity on RAW264.7 macrophages using 0.5–32 µg/mL polysaccharide concentration. A trend that indicated influences of the pre-ethanol treatment and the type of precipitant used was also observed in the amounts of nitric oxide (NO) produced. Overall, produced NO in comparison to LPS was recorded in amounts that indicated immunomodulatory effects. Additionally, the treated cells recorded phagocytosis effect which highly varied in comparison with indicates a stimulatory effect on macrophages. These findings have in all, shown different levels of bioactive effects of the hybrid agaran isolated from *V*. *lanosa* and its potential application for nutraceutical related applications.

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[1035] From bonds to bite: linking multiscale structure and texture of meat and plant-based meat analogues.

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Replicating the complex bite and texture of meat remains a major challenge for plant-based meat analogues, as these depend on a multiscale structure and often differ in their fracture behaviour. In this study, we applied a multiscale structural–textural approach that integrates (i) molecular interactions, (ii) meso-scale architecture, and (iii) macroscopic fracture behaviour to compare meat with three plant-based analogues produced by extrusion, 3D printing, and a newly developed dry spinning method.

Dry spinning represents a promising bottom-up strategy to replicate the hierarchical organization of meat fibers, offering finer structural control and fiber alignment than conventional methods such as extrusion or 3D printing, while maintaining potential for scalability. To evaluate these approaches, we combined mechanical testing with microstructural characterization. In this way, we linked the different processing methods directly to variations in structural hierarchy and fracture behaviour.

At the macro scale, texture profile analysis and dynamic mechanical analysis in compression revealed that meat analogues were generally more anisotropic and viscoelastic than meat. Fiber orientation and interfiber connection played a decisive role for anisotropy and in fracture behaviour. Scanning electron microscopy imaging supported the mechanical data and identified sample-specific fracture patterns. Among the analogues, the dry-spun sample showed the lowest anisotropy and a more homogeneous deformation, indicating stronger and more uniform interfiber connections that resisted localized fracture.
At the meso scale, large amplitude oscillatory shear characterized the storage, and loss moduli, dissipation ratio, and strain-stiffening behavior. Meat showed a short linear viscoelastic region, low dissipation, and gradual stiffening, reflecting a stable, hierarchically organized network. Meat analogues displayed extended linear viscoelastic region ranges, higher dissipation, and earlier onset of plastic deformation, with differences strongly linked to processing technique. The dry-spun analogue exhibited the shortest linear viscoelastic region but maintained an almost isotropic response, like meat. At the micro scale, temperature-dependent small amplitude oscillatory shear confirmed that meat underwent classical thermally induced gelation. In contrast, most analogues were thermally pre-set and showed lower responsiveness to temperature changes. Protein solubility tests in selective solvents showed that meat networks involved a combination of hydrophobic, electrostatic, and disulfide interactions, while the meat analogues were mainly stabilized by hydrophobic interactions.

This multiscale analysis reveals how processing-driven differences at the molecular and meso scale define the macroscopic failure modes of meat analogues. The results provide a mechanistic framework for engineering plant-based products with improved bite and texture, narrowing the texture gap between meat and its analogues.

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[1037] Enhancement of active food packaging system via controlling emulsion stability in hydrogel composition employing multi-emulsifiers

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Active packaging systems designed to effectively deliver bioactive compounds to foods have been developed to maintain product quality and are the major subject of research. We developed humidity-responsive active packaging films by emulsifying lemongrass essential oil (LEO) and mixing the emulsion with polyvinyl alcohol (PVA). Because many factors affect release behavior, application-specific design is required. Among these factors, we compared release behavior across emulsifiers. Of four emulsifiers, two were mixed at controlled ratios to adjust the hydrophilic–lipophilic balance (HLB), and the amount of LEO released at each relative humidity (RH) was measured. Based on this data, we evaluated correlations between HLB, surface loading with LEO release behavior. Correlation coefficient between HLB value and LEO release behavior were 0.67 at 30% RH, 0.54 at 60% RH, and between surface loading value and LEO release behavior were 0.50 at 30%RH, 0.24 at 60% RH. In RH 90%, most of the LEO are released, so they are not significantly affected by these factors. When surface loading was expressed as moles of emulsion per unit area ($mol \cdot m^{-2}$) rather than mass per unit area ($g \cdot m^{-2}$), its correlation with release strengthened, correlation coefficients of 0.77, 0.55, and 0.34 respectively. To interpret these results, we modeled the droplet interface as a geodesic sphere with equilateral triangle, placing emulsifier molecules at the centers of the faces' incircles, and quantified several geometric parameters under this assumption. It suggests that larger intermolecular spacing lowers emulsion stability, facilitating droplet coalescence and collapse. These results identify a new factor that can serve as an additional stability index along with HLB and surface-loading values.

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[1038] pH-responsiveness and environmental stability of chondroitin sulfate and chitosan nanocapsules encapsulating fish oil for wound healing

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Fish oil is rich in nutrients such as omega-3 polyunsaturated fatty acids, which play vital roles in human health, but is highly susceptible to oxidation and rancidity. In this study, chitosan (ChI) and chondroitin sulfate (ChS) were combined through electrostatic interaction to form stable nanocapsules for encapsulating fish oil (ChS-ChI@FO NCs) to enhance stability of fish oil. The nanocapsules were evaluated for their various properties and their responsiveness under different conditions. The encapsulation of fish oil in nanocapsules was confirmed by XRD and FTIR analysis and encapsulation efficiency and loading capacity of 37.56% and 16.37% were achieved, respectively. The particle size of ChS-ChI@FO and ChS-ChI nanocapsules was found to increase significantly at pH 6.0 buffer solution. The release of fish oil was gradual at pH 7.4, reaching approximately 56% after 24 h. ChS-ChI@FO NCs exhibited a significantly enhanced antioxidant and antibacterial ability. ChS-ChI@FO nanocapsules were able to protect fish oil from oxidation at both room temperature and 50 °C for 4 weeks. In addition, the ChS-ChI@FO–loaded hydrogel significantly promoted wound healing, with nearly complete epithelial regeneration observed by day 14. These findings suggest the potential future extension of nanocapsules to the nutraceutical industry or wound inflammation-related applications.

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[1039] Eco-friendly extraction of chitin from squid pens using deep eutectic solvents

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The surge in seafood consumption worldwide generates abundant by-products that can be efficiently converted into value-added products following circular bioeconomy principles. Squid pens are a rich source of β-chitin, yet conventional extraction relies on harsh chemicals. Deep eutectic solvents (DESs) offer a sustainable alternative to traditional strong acids and bases due to their biodegradability, low toxicity, and recyclability. In this study, eight DES systems based on choline chloride, potassium salts, glycerol, organic acids, and urea were evaluated for the deproteinization of squid pens. The squid pens were treated with different DESs at molar ratio of 1:2 with a solid loading of 5%, w/w, and incubated in a shaking water bath at 80 ^{o}C for 2 h. Among them, potassium carbonate: glycerol (PCG), choline chloride: urea (CCU), and choline chloride: acetic acid (CCAA) showed the maximum deproteinization efficiencies of 42.47%, 24.83% and 14.16%, respectively. Optimization of DES molar ratios revealed that PCG at a 1:8 molar ratio achieved a maximum yield 36.74% and deproteinization efficiency of 92.41%; CCU at a 1:8 molar ratio achieved a maximum yield 72.66% and deproteinization efficiency of 90.52%; CCAA at a 1:10 molar ratio achieved a maximum yield 52.68% and deproteinization efficiency of 91.31%. The recyclability of DES was also tested and the extracted chitins were analyzed using FTIR, XRD, and SEM. This approach demonstrates an eco-friendly and efficient route to valorize squid pen waste for high-purity chitin extraction with potential applications in food, health, and cosmetics.

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[1046] Modified Porous Faba Bean and Cassava Starch Obtained by Ultrasound-Assisted Enzymatic and Alcohol Alkaline: A Carrier of Curcumin

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In this study, porous starch (PS) from cassava starch (CS) and faba bean starch (FS) was prepared using ultrasound (US) as pretreatment prior to enzymatic treatment followed by alcohol alkaline treatment (GCWS) to improve properties of modified starch. The effect of

these methods on morphological, ratio of 1047/1022 spectra by FTIR, thermal properties, particle size distribution, solubility and adsorption capacity were studied and compared. The result showed that the surface of PS presented rough surface with small pores on the surface of both starch granules. US-PS and US-PS-GCWS modified samples showed more porous structure on the surface especially observed on CS. The modified PS samples displayed altered significant reduced in relative crystallinity (44.23% - 20.56% reduction) while maintaining their chemical structure as confirmed by FTIR analysis. Compared with unmodified PS, cold water solubility increased by 72.05% and 58.79% for US-PSC-GCWS and US-PSF-GCWS respectively. The water adsorption capacity also increased by 30.56% and 27.66% for US-PS-GCWS on both starches compared to PS alone. All modified PS samples scored higher encapsulation efficiency compared to PS with triple modification achieved highest efficiency and thermal stability for both modified starches. The findings demonstrated that triple modification (US-PS-GCWS) effectively improved the structural integrity, adsorption capacity and encapsulation efficiency of starch, highlighting its potential as a sustainable carrier for thermally sensitive bioactive compounds in functional food application.

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1058 Xanthan–galactomannan hydrogels incorporating soy protein-stabilized oil droplets for tunable texture design: Formulation and physicochemical characteristics

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Emulsion gels are promising candidates for foods designed for at-risk populations because they provide essential nutrients and facilitate safe swallowing. However, few studies have examined how the blending ratios of commonly used food hydrocolloids, xanthan gum (XG), locust bean gum (LBG), and guar gum (GG), together with calcium ions, collectively influence the structure–texture relationship in protein-stabilized emulsion gels suited for diets requiring smooth and safe swallowing. This study aimed to examine the effects of XG–LBG–GG ratio and calcium lactate (CL) addition on the textural

properties, chemical interactions, thermal behavior, and water-holding capacity of soybean protein isolate (SPI)-stabilized emulsion gels.
Nine cylindrical emulsion gel formulations (diameter: 16 mm, height: 12 mm) with various XG–LBG–GG ratios (1% w/w total) were prepared. The formulations contained 15% (w/w) dispersed oil droplets ($d_{4,3}$ = 68.3 μm) and 4% (w/w) hydrophilic SPI (bovine serum albumin standard). Texture profile analysis (TPA) and Fourier transform infrared spectroscopy (FT-IR) were performed to assess physicochemical properties. Subsequently, CL was incorporated at 0–0.2% (w/w) into a formulation that exhibited high hardness, considering the potential weakening of gel hardness by calcium lactate while maintaining low adhesiveness and high cohesiveness to facilitate swallowing. The samples were analyzed using TPA, FT-IR, differential scanning calorimetry, and syneresis measurements to investigate the effects of multivalent cations on network integrity. Two promising formulations (3:3:3 and 3:1:3), which met the Japanese Dysphagia Diet Standard for hardness, adhesiveness, and cohesiveness, were further evaluated using International Dysphagia Diet Standardization Initiative (IDDSI) testing to determine their suitability for safe swallowing.
We found that the three groups with the highest hardness had 35–60% XG and the lowest GG content, whereas the two groups with intermediate hardness also had 35–60% XG and GG levels equal to or lower than LBG. The four softest groups showed no clear XG pattern, but consistently contained the highest GG content. FT-IR analysis showed that shifts in hydrogen-bond-associated peaks did not always correlate with macroscopic hardness, indicating that molecular interactions alone cannot fully explain texture formation. Although low CL (0.05% w/w) increased gel hardness and thermal stability, possibly due to enhanced interchain crosslinking, higher concentrations (0.1% w/w) weakened gel cohesion, likely by reducing network connectivity. Additional CL (0.15–0.2% w/w) partly restored these properties, potentially through nonspecific aggregation and ionic shielding effects. Syneresis was not significantly affected by the CL level, suggesting that water molecules predominantly occupy the available carboxylate sites, thereby minimizing the impact of calcium ions.
The findings underline key formulation insights: (i) hardness can be controlled by adjusting the XG and GG contents, (ii) FT-IR molecular changes do not consistently predict bulk texture, and (iii) calcium ion effects exhibit nonlinear behavior due to competing structural contributions. An IDDSI test confirmed suitability at Levels 4–6, with the 3:3:3 ratio being particularly ideal for moderate swallowing difficulty. These results support the formulation strategies for developing nutrient-dense, cohesive, and safe foods to enhance dietary care for at-risk populations.

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[1069] Physicochemical properties of hydroxypropylated short-chain glucan aggregate

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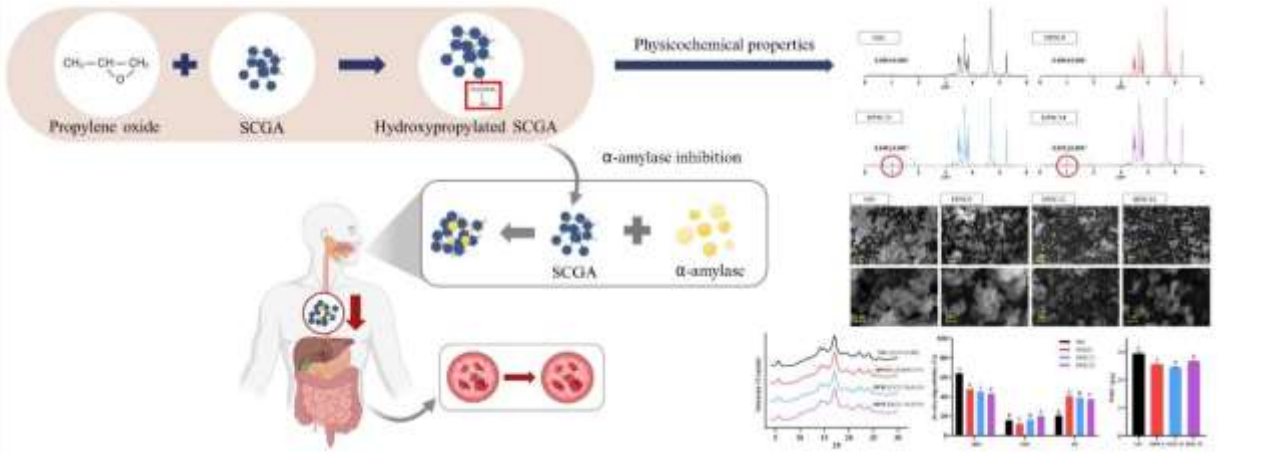

Figure 1. Schematic diagram of Physicochemical properties of hydroxypropylated short-chain glucan aggregate.

Short-chain glucan aggregate (SCGA) is a starch nanoparticle formed by self-assembly of short-chain glucans (SCGs) obtained through enzymatic debranching of starch. It is a submicron-sized particle that functions as a type of resistant starch and exhibits notable inhibitory effects on α-amylase activity. Therefore, SCGA has been studied as a promising material due to its potential to attenuate glycemic response. Hydroxypropylation (HP) is a chemical modification method that hydroxypropyl groups replace the hydroxyl groups of starch, thereby delaying starch retrogradation and increasing paste transparency. HP increases resistant starch content and enhances water retention, consequently inhibiting amylase activity. However, there have been no reports on the properties of hydroxypropylated SCGA (HPSC). Thus, this study aimed to investigate the physicochemical properties of hydroxypropylated SCGA.

SCGA was produced by gelatinizing waxy corn starch, debranching it with pullulanase, and self-assembling the resulting SCG. HP was carried out by inducing an ether bond with 0 (HPSC0), 12% (HPSC12), and 24% (HPSC24) propylene oxide at pH 11.5. The degree of substitution (DS), DSC, XRD, NMR, SEM, *in-vitro* digestibility, and α-amylase inhibition of the samples were analyzed.

Native SCGA (NSC) and HPSC0 showed no DS, whereas HPSC12 and HPSC24 revealed DS values of 0.048 and 0.092, respectively. Annealing treatment under alkaline conditions during hydroxypropylation prevented agglomeration of SCGA particles. Moreover, the structural rearrangement induced by annealing resulted in the highest enthalpy and relative crystallinity in HPSC0. However, in HPSC24, the DS was sufficiently high to offset the effects of annealing, leading to decreases in both enthalpy and relative crystallinity. These results suggest that the introduced hydroxypropyl groups in HPSC24 interfered with double-helix formation and reduced the development of crystalline

structures. Water retention capacity decreased in HPSC0 because alkaline treatment formed particles with a more ordered structure, but it showed an increase after hydroxypropylation. For *in-vitro* digestibility, all HPSC samples exhibited higher RS contents than NSC. HPSC0 showed the highest RS content, indicating that the structural reorganization caused by annealing most effectively hindered enzymatic digestion. According to a previous study, SCGA was reported to act as a competitive-type inhibitor of α-amylase. HPSC24 demonstrated the strongest α-amylase inhibitory effect, possibly due to their loosened double-helical structures leading to not only compete with the substrate but also entrap α-amylase. Overall, hydroxypropylated SCGA could enhance RS content and inhibit α-amylase activity, due to alkaline annealing and their looser structure formed by hydroxypropyl substitution, respectively. Hydroxypropylated SCGA have potential as a material capable of lowering postprandial glycemic response and can be utilized as a promising carrier for other bioactive compounds.

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[1070] Formation characteristics of 3D-printed food using sweet potato (*Ipomoea batatas* L.) starch gel

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Extrusion-based 3D food printing is a relatively new technology used to create intricate shapes layer by layer by precisely extruding a viscoelastic food material on a printing stage. The food material selected was sweet potato starch gel given that sweet potato starch is widely used as an ingredient in the food industry. However, the ability of gels to form intricate 3D shapes from initially extruded filaments has not been well studied. Therefore, this study aimed to investigate the effects of printing conditions on multilayer printing of sweet potato starch gel using an extrusion-based 3D food printer with different nozzle diameters.
We determined the printing conditions (i.e., moisture content of the gel, print temperature, print speed, and model filament width and height) appropriate for the precise extrusion of single filaments of sweet potato starch gel for each specified nozzle diameter of 1.5 mm

and 4.0 mm. When 3D food printing of square prisms with a base area of 48 mm × 48 mm was performed using precisely extruded filaments, it was necessary to perform additional 3D printing modifications (i.e., nozzle clearances for the 1st layer and succeeding layers, number of polygons per layer, and fill factor) for each nozzle diameter to improve the appearance of the 3D-printed material. As the number of layers increased, the lengths of the side of the top layer decreased gradually, whereas there was no significant difference between the lengths of the bottom layer side (p = 0.05). Consequently, the degree of flatness, which is the ratio of the length of the bottom layer to that of the top layer, increased linearly with the number of layers, illustrating the spreading of the hot gel in the top layer, whereas cooling and solidification occurred in the bottom layer. Nevertheless, it is possible to create intricate 3D shapes using sweet potato starch gel following the selected printing conditions and recommended number of layers, which are 4 and 3 for the 1.5-mm and 4.0-mm nozzles, respectively, based on the results obtained from this study.

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1072 Effect of type of soy-based foods on their *in vitro* digestibility using a Gastric Digestion Simulator

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Various soy-based foods are being consumed in East Asia. Their texture, microstructure, and digestibility can be influenced by food processing methods. The gastric digestion simulator (GDS), which is equipped with a quantitatively simulated human gastric peristalsis, enables direct observation and analysis of the digestion behavior of food particles. The purpose of this study was to investigate the influence of processing methods on the *in vitro* gastric digestibility of soy-based foods using GDS.

Sliken tofu, koya-dofu, okara, and boiled soybeans were purchased from local markets. Silken tofu and koya-dofu were cut into 5 mm cubes. The okara was rolled into balls with diameters of 10 mm. Each boiled soybean sample was cut in half. Eighty grams of soy-based food samples were used for *in vitro* digestion experiments. Each food

sample was placed in a beaker containing 30 mL of simulated salivary fluid (SSF, pH 7.0) for 2 min. Afterwards, the mixture was introduced into the GDS vessel containing 240 mL of simulated gastric fluid (SGF, pH 1.3). The GDS experiments with simulated gastric peristalsis (1.5 cycles/min) and 0.1 M HCl addition (45 mL in total) were performed at 37 °C for 3 h. Proteins in the gastric contents sampled during the GDS experiment were analyzed using HPLC.

During the 180 min of the GDS experiments, the silken tofu particles quickly disintegrated owing to their soft and fragile texture. Koya-dofu particles with a sponge-like texture did not disintegrate as quickly as silken tofu particles. SGF was considered to penetrate the Koya-dofu particles easily and cause sudden disintegration after 120 min. As okara has a very crumbly texture, the okara bolus quickly dispersed in the GDS vessel without the disintegration of okara particles. For boiled soybean particles, most of the cotyledons disintegrated during the first 30 min, whereas the outer shell remained undigested after 180 min. The HPLC results demonstrated that the protein digestibility of the gastric contents sampled during the GDS experiments was affected by the type of soy-based food.

The use of our GDS demonstrated how the type of soy-based food affects the physical and chemical gastric digestion.

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[1078] Preparation a sugar-sodium alginate-maltodextrin composite gel with sustained releasing properties

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A composite gel with sugar sustained-releasing property, specific designed for endurance athletes during high-intensity and long-duration competitions, was developed and its physicochemical properties and *in vitro* releasing behavior were evaluated as well. Sodium alginate (NaA) combined with maltodextrin (DE10) were used to prepare the gel matrix, which allowed to carry out high amounts of glucose and fructose to meet the requirements of at least 30g of sugar per hour for 2-3 hours. The appearance and texture of the gel made with 1% NaA and 5 mM glucono delta-lactone (GDL) were superior for other gel formulations. The addition of maltodextrin in NaA gel significantly improved the sustained-releasing effect of the composite gel, while the transparency decreased and hardness increased with increasing the amount of maltodextrin and storage time because of starch retrogradation. Although sugar-releasing behavior became slightly less stable after 1-month storage, adding high amount of DE 10 did closely meet the required sugar-releasing behavior in the first two hours. Subsequently, the sugars were continuously

released due to the maltomextrins digestion through the hydrolysis of pancreatic amylases in simulated intestinal fluid to maintain the sugar level. For commercial purposes, a stable gel with good tasting characteristics and control-releasing function for a reasonable shelf-life (6 months) are critically important. Thus, the composite gel was prepared by adjusting pH to meet the low-acid food regulation by using malic acid. As a result, a composite gel made with 0.48% NaA and 22% DE 10 containing 30% sugars (glucose:fructose=2:1) with 5 mM GDL as coagulant under 14mM of malic acid solution are suitable for energy gel preparation for endurance athletes, who may consume it before competition then a stable blood glucose level can be maintained during the early stage of racing.

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[1080] Bioactive Polysaccharides from *Halymenia durvillei*: Structural Characterization and Functional Applications in Immunomodulation and Wound Healing

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Polysaccharides from algae have shown promising potential in various biomedical applications due to their biodegradability, biocompatibility, and non-toxic properties. In this study, we explored the bioactivity of polysaccharides extracted from *Halymenia durvillei* (HD, from Tomasa, Bolinao, Pangasinan) using hot (95 °C) and cold (25 °C) extraction methods. The polysaccharides were characterized by HPLC-SEC, FTIR, and ^{1}H NMR spectroscopy. We assessed their effects on cell proliferation, migration, nitric oxide production, and phagocytosis using RAW264.7 cells, as well as their impact on inflammation and wound healing in HaCaT cells. The hot-extracted polysaccharide fraction, a highly sulfated galactan. (λ-carrageenan), significantly stimulated RAW264.7 cell proliferation and migration. In contrast, the cold-extracted fraction inhibited cell proliferation at higher concentrations (0.5 µg/µL etc.) but enhanced phagocytosis activity. Furthermore, RAW264.7 cells treated with the hot extract showed a significant reduction in LPS-stimulated nitric oxide (NO) synthesis ($p<0.0001$). In wound healing assays, HaCaT cells treated with HD polysaccharides exhibited significantly faster proliferation and migration ($p<0.0001$). Caco-2 cells exposed to the polysaccharide fractions showed elevated *TGF-β1* expression and no detectable *TNF-α* expression at 24 h, indicating minimal inflammatory response and supporting their potential safety for future medical applications. Additionally, the anticoagulant activity of HD-derived

polysaccharides was confirmed through an activated partial thromboplastin time (aPTT) test, showing a lower anticoagulant effect among the fractions tested. This study demonstrated that polysaccharides from *Halymenia durvillei* exhibited significant bioactivity, including promoting wound healing, enhancing immune response, and exhibiting anti-inflammatory properties. These findings suggest that HD-derived polysaccharides have potential applications in wound care, gastrointestinal health, and could be exploited in the food, cosmetic, and pharmaceutical industries.

Keywords: Carrageenan; NMR; FTIR; HPLC-SEC; Immunomodulatory; Pro-inflammatory cytokines; Anti-coagulant; wound healing.

Acknowledgment

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[1081] Molecular Weight-Dependent Bioactivities of Hydrolyzed *Chondrus crispus* Polysaccharides: Anti-Inflammatory and Colon Cancer Cell Inhibition

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Algal polysaccharides, known for their biodegradability and biocompatibility, show significant promise for biomedical applications. *Chondrus crispus* (CC), a red alga, is a rich source of these polysaccharides, and this study investigated their bioactivities following auto-hydrolytic degradation. Polysaccharides were extracted and hydrolyzed from *C. crispus*, and their molecular weight was determined using size-exclusion chromatography (SEC). Structural analysis was performed using Fourier transform infrared spectroscopy (FTIR) and proton nuclear magnetic resonance (^{1}H NMR) spectroscopy. A reduction in molecular weight after hydrolysis confirmed the successful breakdown of larger polysaccharide chains into smaller fragments. To evaluate the biological activity of the hydrolyzed polysaccharides, RAW264.7 cells were used to assess proliferation, migration, nitric oxide (NO) production, and phagocytic activity. The effects of the polysaccharide fractions were also tested on HDF, HCT-116, and Caco-2 cell lines. Specifically, the inflammatory responses in Caco-2 cells were measured by analyzing cytokine expression tumor necrosis factor-alpha (*TNF-α*), transforming growth factor-beta 1 (*TGF-β1*) and the chemokine monocyte chemoattractant protein-1 (*MCP-1*). The hydrolyzed *C. crispus* polysaccharides significantly modulated inflammatory

responses and promoted wound healing, as evidenced by enhanced scratch assays. The 24-h, 50 kDa polysaccharide fraction (CC-24h) inhibited the proliferation and migration of HCT-116 (colon cancer) cells, while the native polysaccharide fraction (CC-2A) at 0.5 µg/µL had no effect on cell proliferation within 24 h. Notably, CC-derived polysaccharides resulted in a substantial reduction in LPS-stimulated NO production ($p<0.0001$) in RAW264.7 cells after 24 h. Furthermore, HDF cell proliferation was significantly increased after treatment with CC-0 polysaccharides (*p<0.0001*), which had a molecular weight of approximately 2700 kDa. In contrast, treatment of Caco-2 cells with all polysaccharide fractions led to increased TGF-β1 expression, but the absence of *TNF-α* expression at 24 h, suggesting the safety of these fractions for future biomedical applications. Additionally, unhydrolysed polysaccharide fractions (at 0.13 µg/µL) showed no cytotoxic effects in Caco-2 cells over 24 h. These findings indicate that the bioactivity of *C. crispus*-derived polysaccharides is influenced by their molecular weight, with effects varying across different cell types. Given their potential for promoting wound healing and alleviating gastrointestinal issues, these polysaccharides have promising applications in the food, cosmetic, and pharmaceutical industries.

Keywords: Lambda carrageenan; NMR; FTIR; HPLC-SEC; Immunomodulatory; Pro-inflammatory cytokines; Anticancer.

Acknowledgment
This research was funded by Estonian Research Council grants PRG1808

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[1083] Effects of oil type and emulsion particle size on emulsion gel properties for animal fat replacement

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In this study, we investigated agar–soy protein isolate emulsion gels as plant-based fat mimics, focusing on the effects of oil type and droplet size. Emulsion gels were prepared with canola oil, rice bran oil, or eugenol in either microsized (~69–77 µm) or nanosized (~120–262 nm) forms, and their properties were systematically compared with pork fat. Nanosized emulsions produced finer and more homogeneous networks, while microsized ones showed higher mechanical strength. Rice bran oil nanosized gels exhibited balanced strength, high water-holding capacity, and low syneresis, indicating enhanced network compactness and stability. These effects were associated with phenolic components that reinforced the gel matrix. Eugenol-based gels showed a dual role of phenolics: microsized

gels enhanced hardness and freeze–thaw resistance, whereas nanosized gels exhibited reduced structural integrity. Thermal analysis confirmed the absence of triglyceride melting transitions, although rice bran oil nanosized gels showed the highest transition enthalpy. FT-IR analysis revealed stronger protein–phenolic interactions in microsized gels and tighter molecular packing in nanosized ones. These findings highlight the potential of combining phenolic-rich oils with droplet-size control to design structured plant-based fats.

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[1084] Hydrocolloid-mediated mineral partitioning via intact rice in traditional Boil-Up: A culturally anchored strategy for Chronic Kidney Disease management

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Background: Chronic kidney disease (CKD) is prevalent in New Zealand and disproportionately affects Māori, underscoring the need for culturally anchored dietary strategies. CKD guidelines recommend limiting potassium to reduce hyperkalaemia risk and sodium to support blood pressure and proteinuria control. Boil-up, a traditional Māori one-pot meal of meat, root vegetables, and greens, can elevate dietary K^+ and Na^+ due to K-rich greens and salted bones. Accordingly, this study aimed to test a culturally grounded adaptation (adding intact Basmati rice in mesh bags during simmering) to harness hydrocolloid-mediated cation partitioning, reducing mineral (particularly K^+) content in the served meat/vegetable portion while preserving the dish's cultural integrity.
Methods: Standardised boil-up was prepared with intact Basmati rice (0, 30, 60, 100 g) added during the final 30 min of simmering. Minerals (K^+, Na^+, and Ca^{2+}) in the served food and recovered rice were quantified by MP-AES. Proximate composition was also measured. Data are presented as mean±SEM (n=3). One-way ANOVA with Tukey's post-hoc tested treatment effects ($p < 0.05$), with effect sizes (η^2) were reported.
Results and Mechanism: Mineral reductions scaled with rice amount ($p < 0.05$). At 100 g, for example, K^+ decreased by 40.2±2.0%, Na^+ by 53.4±1.6%, and Ca^{2+} by 39.6±8.3%, with corresponding enrichment of cooked rice. Effect sizes were large to very large, consistent with hydrocolloid-driven cation partitioning into gelatinising starch. The proximate analysis showed that carbohydrate content of the boil-up increased with

increasing the rice mass, as expected. Slight decrease in crude protein was also observed, likely due to surface area-to-volume effect; i.e., each grain is exposed to a greater volume of nutrient-rich cooking water in smaller rice portions, resulting in higher nutrient absorption per gram when data is normalised to per 100 g. As grains hydrate and starch gelatinises, mineral-rich broth diffuses into the grain down a concentration gradient. The hydrated starch matrix and viscous boundary layer from surface-leached starch retard back-diffusion, enabling net $K^+/Na^+/Ca^{2+}$ transfer.
Significance: This simple, culturally compatible cooking step offers a household-level CKD strategy—substantially lowering K^+ and Na^+ exposure in the portion consumed by CKD patients while producing a nutrient-enriched rice portion for other diners. By working within a traditional food using intact grains and boiling, it supports cultural acceptance and shared family meals without separate dishes.
Keywords: rice hydrocolloids; cation partitioning; dietary potassium; sodium reduction; traditional Māori foods; CKD nutrition.

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1089 Effect of xanthan gum sol on *in vitro* gastrointestinal digestibility of food emulsion blends

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Food emulsions have been widely used as delivery systems for nutrients. In elderly and dysphagia diets, thickened foods containing hydrocolloids such as xanthan gum (XG) are widely used to prevent miss swallowing. These thickeners not only modify the rheological properties of liquid foods but may also influence their digestive characteristics. It is therefore important to clarify how the addition of the XG sol affects lipid digestion in emulsions. Conventional studies have mainly used monomodal emulsions, which makes precise control of lipid digestibility difficult. Recently, we proposed a food emulsion blend (FEB) prepared using two monodisperse emulsions with different droplet sizes. In this study, we investigated the *in vitro* gastrointestinal digestibility of FEBs mixed with XG sols.

Oil-in-water emulsions were prepared using 1.0% (w/w) Tween 20 aqueous solution as the continuous phase and refined soybean oil as the dispersed phase. Monodisperse emulsions were produced via premix membrane emulsification equipped with tubular

Shirasu porous glass (SPG) membranes (mean pore sizes (d_p): 1.1, 10.0, and 50.4 µm). Two emulsions with different droplet sizes were mixed in equal volume to prepare FEBs. Thickened aqueous solutions were prepared by dissolving 1% or 5% (w/w) XG in Milli-Q water containing 0.05% (w/w) blue dextran and stirring for 30 min using a homomixer For *in vitro* gastric digestion, FEB (7.5 mL), thickened solution (7.5 mL), and simulated gastric fluid (15 mL) were incubated at 37 °C under shaking (115 strokes/min) for 2 h, followed by intestinal digestion with an equal volume of simulated intestinal fluid at 37 °C for 2 h. Particle size distribution and free fatty acid (FFA) release rate were measured, and droplets during digestion were observed using a fluorescence microscope.

FEBs mixed with 1% XG sol (1%XG-FEB) were macroscopically homogeneously dispersed in the simulated gastric fluid and remained as a liquid phase after gastric digestion. In contrast, the samples mixed with 5% XG sol (5%XG-FEB) did not disperse macroscopically homogeneously, and fine lumps were observed during gastric digestion. The 1%XG-FEB maintained its bimodal particle size distribution during gastric digestion. This stability was likely because of interfacial coverage by Tween 20 and XG. For the 5%XG-FEB, a new peak appeared in the 100–2000 µm range after gastric digestion, suggesting the formation of XG-derived aggregates. The distinct bimodal droplet distribution of the FEBs disappeared during intestinal digestion. FFA release profiles varied depending on the droplet size combination. In the 1%XG-FEB, the maximum FFA release after 120 min (φ_{max}) ranged from 28.6% to 39.6%, showing a positive correlation with the total droplet surface area. In contrast, in the 5%XG-FEB, φ_{max} ranged from 34.2% to 40.9%, but no correlation with surface area.

These results suggest that FEBs stabilized with a low concentration of XG have the potential to control lipid digestibility through the combined effects of droplet structure and system viscosity.

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1094 Green hydrothermal valorisation of apple pomace: co-recovery of pectin, phenolics, and sugars with development of functional dietary fibres

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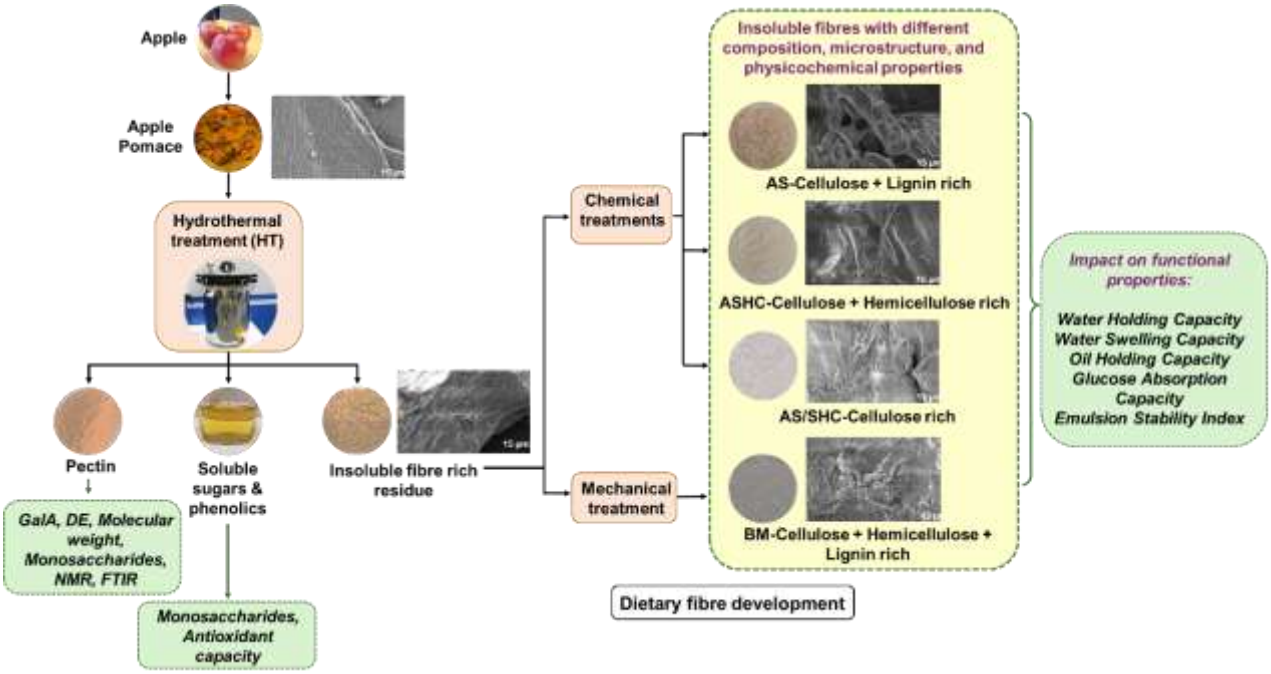
This study presents a green hydrothermal approach for simultaneously recovering pectin, phenolics, and sugars from apple pomace (AP), followed by the preparation of functional dietary fibres from the resulting fibre-rich residue. Optimised treatment at 120 °C for 15 min maximised recovery yields while maintaining phenolic antioxidant activity and minimizing pectin degradation. The extracted pectin exhibited a degree of esterification of 84.5%, uronic acid content of 83.8% and molecular weight of 161 kDa, with FTIR, ^{1}H NMR, TGA, rheology and gelling analyses confirming structural and functional characteristics comparable to commercial and acid-extracted pectin. Co-extracted phenolic-sugar fractions were rich in glucose (92 %w/w and exhibited strong antioxidant capacity alongside a monosaccharide profile similar to conventional ethanol extracts. This sustainable hydrothermal approach enables efficient co-recovery of hydrocolloid-relevant components while reducing reliance on chemical-intensive extraction methods. Chemical (alkali, sodium hypochlorite) and mechanical (ball milling) post-treatments generated fibres with varied compositions, microstructures, and physicochemical attributes, including differences in zeta potential, particle size, and water contact angle. Chemical modifications produced cellulose-, cellulose + hemicellulose-, and cellulose + lignin-rich fibres more open microstructures, enhanced hydrophilicity, and higher surface charges relative to the compact lignocellulosic fibres generated by ball milling. Highly charged, hydrophilic, cellulose-rich fibres with thin sheet-like morphologies showed high water-holding (26.44 g/g), swelling (24.48 mL/g), and glucose adsorption capacities (11 mmol/g), whereas porous cellulose-rich fibres containing lignin and oil exhibited enhanced oil-holding capacity (19.7 g/g). Notably, hydrothermally treated fibres enriched with pectin, protein, and oil, possessed amphiphilic surfaces, small particle size, and rough morphology, which contributed to their strong emulsifying behaviour (EAI: 66.8 m2/g; ESI: 106.7 min). Overall, these findings highlight the potential of a green hydrothermal processing for producing AP-derived pectin, phenolics, and sugars, and identify key structural determinants for designing next-generation functional dietary fibres from residual biomass.
Keywords: Apple pomace; Pectin; Phenolics; Soluble sugars; Dietary fibres; Structure-function relationship, Sustainable processing



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1100 Self-gelation of xanthan gum by physical modification

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Xanthan gum (XG) is a water-soluble extracellular polysaccharide that exhibits high viscosity and pronounced shear-thinning behavior. In this study, it was found that an aqueous mixture of unmodified XG and XG modified by high-temperature and high-pressure treatment (autoclaving) forms gels after a heat–cool process. While XG has been known to interact with other polysaccharides such as locust bean gum or glucomannan to form gels, gelation induced by mixing unmodified and modified XG can present a novel mechanism.

Modified XG (XG_{AC240}) was prepared by autoclaving a 1.5 wt% XG solution at 135 °C for 240 min, followed by precipitation with isopropanol to recover. Molecular weights were determined using the size exclusion chromatography coupled with multiple-angle light

scattering, whereas organic acid concentrations were quantified by the post-column detection and high-performance liquid chromatography. Rheological properties for the aqueous mixtures of unmodified and modified XG were examined on a MCR 302 rheometer before and after the heat–cool cycle, which was performed by holding the sample at 80 °C for 10 min, cooling to 10 °C at a rate of 5 °C/min, and maintaining at 10 °C for 180 min prior to the measurement of the frequency dependence of dynamic viscoelasticity in the range of 0.1–100 rad/s. Atomic force microscopy (AFM) observation was carried out using a MultiMode 8-HR in tapping mode on samples prepared by air-drying the aqueous mixtures on a mica surface.

Results showed that XG_{AC240} had a lower weight-average molecular weight (approx. 380K) compared to unmodified XG (approx. 1,600K). In addition, pyruvic acid content for XG_{AC240} decreased to 1.4 wt% from 5.9 wt% for unmodified XG. Rheological analysis revealed that both 1.5 wt% untreated XG and the mixed system for 0.75% unmodified XG and 0.75% XG_{AC240} displayed weak-gel type mechanical spectra. The mixed system exhibited lower frequency-dependence of dynamic storage modulus compared to unmodified XG, indicating more solid-like structure for the mixed system. AFM imaged the aggregations between unmodified XG and XG_{AC240}, forming the supramolecular assemblies.

These findings suggest that the gelation occurs as a result of the supramolecular cluster formation between the two components, and the resulting structure is more likely to be the fractal-like network rather than the homogeneous polymer matrix. To support this hypothesis, circular dichroism spectroscopy is currently being conducted on the modified XG. This study provides new insights into the design of xanthan-based gels through controlled thermal modification, offering potential applications in food and material sciences.

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1101 Physicochemical properties of dual modified rice flour by heat annealing and pressure annealing treatment

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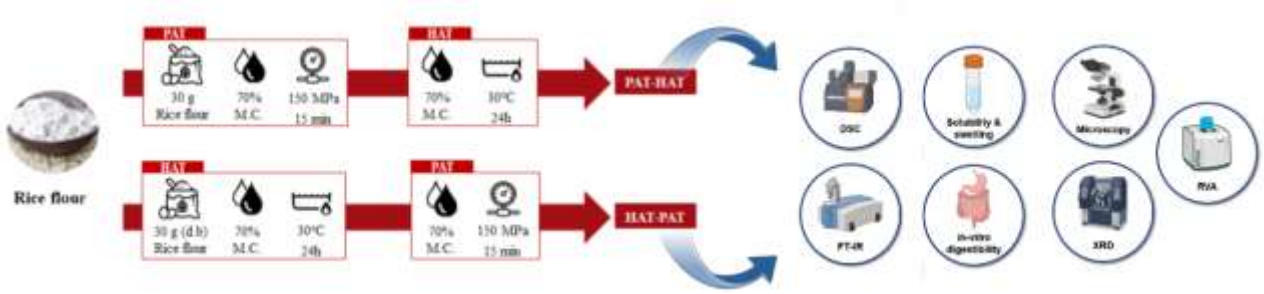

Figure 1. Schematic diagram of physicochemical properties of dual modified rice flour by heat annealing and pressure annealing treatment.

Rice is a staple carbohydrate source widely consumed in Asian countries. However, its tendency to rapidly increase blood sugar levels has limited its broader application in food processing. Therefore, recent studies have focused on slowing digestion of rice, using physical modification methods. Heat-annealing treatment (HAT) and pressure-annealing treatment (PAT) have paid attention for their effectiveness in reducing starch digestibility and promoting health benefits. However, research on the combined effect of HAT and PAT remain limited. Therefore, effects of each modification method and its synergistic effect on the physicochemical properties of rice were investigated.

Rice flour was packed into PE pouches. The moisture content was adjusted to 70% by adding distilled water. PE pouches for HAT were annealed in a water bath at 30 °C for 24 h, while those for PAT were treated with high pressure at 150 MPa for 15 min at room temperature. The rice flour suspension was then centrifuged at 2,232 × g for 15 min. HAT-PAT and PAT-HAT were treated under the same conditions with individual treatments, with only the sequence of treatment was altered. Physicochemical properties of rice flour were analyzed using morphology, FTIR, XRD, DSC, RVA, *in-vitro* digestibility.

Under uncooked conditions, none of the treatments increased RS content compared to native rice. However, after cooking, all samples showed a decrease in SDS and an increase in RS content. In the case of single treatments, PAT resulted in a greater increase in resistant starch (RS) than HAT. In the dual-treated samples, the HAT–PAT showed a higher RS content compared to PAT–HAT. In DSC thermal properties. HAT resulted in an increase in double helix melting enthalpy (ΔH), whereas PAT did not show a significant difference. All modified samples showed decreased ratios compared to native rice flour, indicating that short-range molecular order was partially disrupted. On the other hand, relative crystallinity (RC) increased with treatment. PAT, changes in the proportions of β-sheet and α-helix structures were observed. In RVA analysis, Peak viscosity did not show significant difference between native and modified samples. Breakdown viscosity significantly decreased in HAT, but not in PAT. Additionally, setback viscosity increased only in the PAT sample, suggesting a higher tendency for retrogradation during cooling despite the reduced stability during heating. However, when PAT was combined with HAT, it showed improved shear and heating stability, showing a reduced breakdown viscosity. In addition, setback viscosity was reduced in dual-modified samples, indicating that combining PAT with HAT altered its pasting properties. Morphological observations reveal altered aggregation and dispersion patterns of starch and protein, which influence starch-protein interactions and digestibility.

As a single treatment, HAT reduced the digestibility of rice flour by promoting the formation of double helices, thereby enhancing granular integrity and starch chain rearrangement. In contrast, PAT made the starch granules more compact and induced protein denaturation, which also led to a significant decrease in digestibility. When these two treatments were combined, the RS content reached the highest level among all samples by compensating for the limitations of each individual treatment.

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1102 Physicochemical properties and *in vitro* digestibility of heat-moisture treated and pressure-moisture treated rice flour

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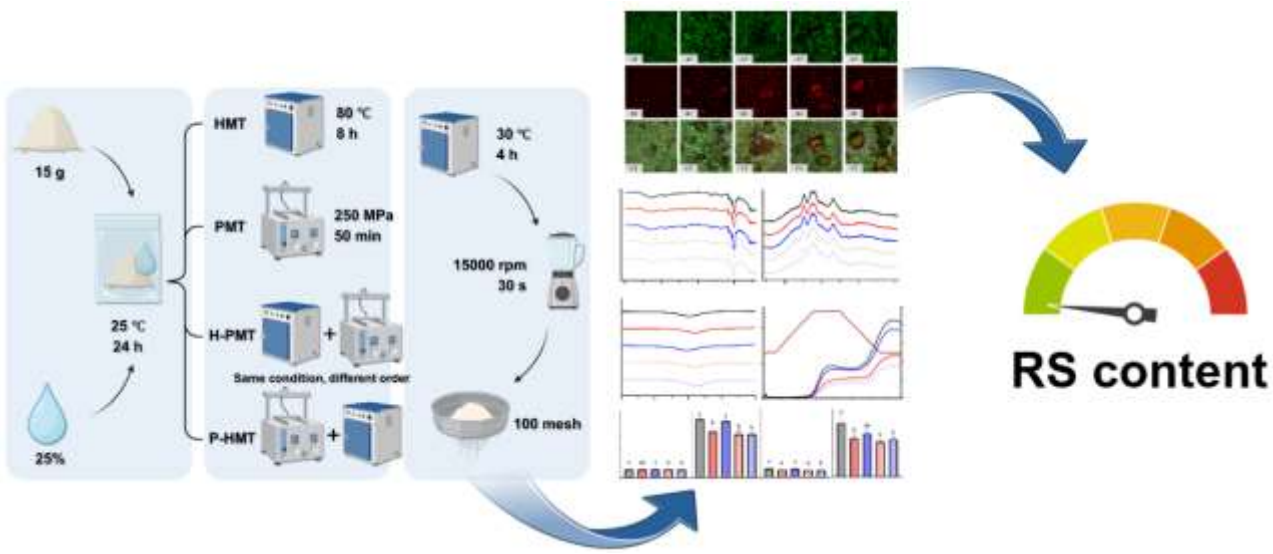

Figure 1. Schematic diagram of physicochemical properties and *in vitro* digestibility of heat-moisture treated and pressure-moisture treated rice flour.

In Asia, rice has traditionally been consumed primarily in the form of cooked rice. However, with the diversification of dietary patterns, the consumption of processed rice-based foods has been steadily increasing. Responding to this trend, efforts have been made to modify starch-based ingredients such as wheat flour and rice flour to reduce their digestibility while altering their functional properties. Among the various techniques, Heat Moisture Treatment (HMT) and Pressure Moisture Treatment (PMT) are typical physical modification methods that offer improved safety compared to chemical methods. In this

study, the effects of single and dual modification using HMT and PMT on physicochemical properties and in-vitro digestibility of rice flour were investigated to provide the potential of the modified rice flour as a less digestible ingredient in processed foods.

Rice flours was placed in a polyethylene pouch, and distilled water was added to adjust the moisture content to 25% by allowing it to equilibrate for 24 h. HMT was performed at 80 ℃ for 720 min, while PMT was performed at 250 MPa for 50 min. Dual modifications were carried out HMT first and followed by PMT (H-PMT) or in the reverse order (P-HMT), using the same conditions of the previous individual treatment. Physicochemical properties of rice flour were analyzed using CLSM, FTIR, XRD, DSC, solubility, swelling power, RVA, *in-vitro* digestibility.

CLSM results showed that Both HMT and PMT induced protein aggregation, which altered the morphology of starch granules. In all modified samples, proteins were found to form large aggregates surrounding starch granules. FT-IR results confirmed that the large aggregates observed morphologically originated from protein denaturation, while the short-range molecular order of starch remained unchanged. In contrast, XRD analysis showed that the long-range molecular order was modified, suggesting rearrangement of amylopectin double helices and altered cluster packing within the granules. HMT and dual-treated samples exhibited significantly higher thermal stability compared with the native sample, whereas PMT did not show a significant difference. HMT and dual-treated samples exhibited significantly lower solubility, swelling power, and viscosity than the native sample. Digestibility behavior differed between uncooked and cooked samples. Before cooking, protein aggregation surrounding the granules played a dominant role in limiting enzyme accessibility, whereas after cooking, the rearranged internal structures became the main factor affecting digestibility. These results demonstrate that both HMT and PMT significantly modified the morphological and structural properties of rice flour, thereby influencing its physicochemical and digestibility characteristics. Moreover, the dual treatments produced varying effects depending on the treatment sequence.

Overall, the findings suggest that physically modified rice flour produced by HMT and PMT possess potential as less digestible functional ingredients in food processing. Future studies should apply these modification methods to various rice cultivars to evaluate varietal differences and explore their potential applications in rice-based food products to assess substitutability and digestibility reduction effects.

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1105 Development of multifunctional protein–polysaccharide complex-based emulsions, foams and emulsion gels for food applications

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Oil-in-water (O/W) emulsions are indispensable in products such as salad dressings, mayonnaise and sauces, where stability at acidic conditions is critical. Although egg yolk offers excellent emulsifying and foaming performance at acidic conditions, its use is limited by allergenicity, flavour carry-over and sustainability concerns. The present study explored xanthan gum (XG) complexes with whey protein isolate (WPI) or soy protein isolate (SPI) as natural, egg-free colloidal stabilisers functioning as emulsifiers for emulsions and emulsion gels, and investigated whether this system could stabilize foams.

At pH 4.0, electrostatic interaction between WPI and XG generated nano-assemblies (~100 nm) with a ζ-potential of –37.3 mV, compared with +6.94 mV for WPI alone. These WPI–XG complexes produced finely dispersed O/W emulsions that showed no visible creaming after 28 days at 25 °C. Cryo-SEM images revealed that the complexes adsorbed at the oil–water interface through a WPI core, while interconnected fibrillar XG structures bridged adjacent complexes to build a steric barrier layer; this characteristic architecture is considered the principal mechanism suppressing droplet coalescence in the emulsion.

SPI–XG complexes, prepared at identical acidic conditions, delivered plant-based O/W emulsions of comparable stability. Plant-based patties formulated with this emulsion gel gelled with κ-carrageenan, konjac mannan and methylcellulose also showed reduced weight loss after cooking and after frozen reheating than counterparts prepared with liquid canola oil, suggesting that oil droplets were effectively trapped within the gel matrix and that oil leakage was efficiently controlled. These results collectively demonstrate the effectiveness of the emulsion gel as a clean-label, allergen-free fat substitute.

Furthermore, experimental results indicated that these protein–polysaccharide complexes not only improve foaming capacity but also enhance foam stability, suggesting their potential use beyond emulsion-type foods. The detailed mechanism of this effect will be examined in future studies, in which we will also investigate optimal combinations of component materials for different food matrices.

Our findings highlight the versatility of XG-mediated protein complexes as multifunctional building blocks for next-generation food hydrocolloids. By providing acid-resistant emulsification, superior foaming and robust gelation in a single system, these complexes support the development of low-protein, egg-free and plant-forward products with improved texture, sensory appeal and environmental sustainability.

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1113 Influence of pH and heat-treatment on the physicochemical, interfacial and emulsifying properties of hemp seed protein dispersions.

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The development of protein–polysaccharide conjugates via the Maillard reaction represents a promising strategy to enhance the techno-functional properties of food proteins while simultaneously incorporating bioactive or prebiotic carbohydrates. In this study, whey protein isolate (WPI) was conjugated with two distinct prebiotic carbohydrates—Inulin and galactooligosaccharides (GOS)—and the structural, functional, and interfacial characteristics of the resulting conjugates were compared. Reaction conditions were optimized to promote controlled conjugation while minimizing excessive browning. The degree of conjugation, structural modifications, and changes in molecular properties were characterized using SDS-PAGE, FTIR spectroscopy, fluorescence analysis, and browning index measurements.
Both WPI–Inulin and WPI–GOS conjugates exhibited improved solubility and thermal stability relative to native WPI, although the magnitude of these improvements differed depending on the carbohydrate type. WPI–GOS conjugates showed a higher degree of glycation, likely due to the smaller molecular size and higher reducing sugar activity of GOS, leading to more extensive protein modification. In contrast, WPI–Inulin conjugates, characterized by lower reducing-end activity and higher molecular weight, generated less pronounced structural alterations but produced thicker conjugate layers at interfaces. Interfacial tension measurements and droplet stabilization tests revealed key functional differences: WPI–GOS conjugates displayed faster adsorption kinetics and improved emulsifying capacity, attributed to their enhanced solubility and increased hydrophilicity following glycation. WPI–Inulin conjugates, however, formed more viscoelastic and robust interfacial layers, resulting in superior resistance to coalescence and improved long-term emulsion stability. These findings demonstrate that carbohydrate size, structure, and reducing-end activity critically influence the interfacial behavior of protein–carbohydrate conjugates.
Beyond their functional performance, both conjugates provide additional prebiotic benefits. GOS conjugates deliver short-chain oligosaccharides known for selective stimulation of bifidobacteria, while Inulin conjugates incorporate longer fructans capable of modulating gut microbiota composition and enhancing fermentation profiles in the colon. The successful formation of WPI–Inulin and WPI–GOS conjugates therefore offers dual advantages: enhanced protein functionality and the integration of prebiotic components into delivery structures.
Overall, this comparative study highlights how the choice of carbohydrate significantly affects the molecular, interfacial, and techno-functional properties of WPI-based conjugates. WPI–GOS conjugates excel in improving protein solubility and rapid interfacial adsorption, whereas WPI–Inulin conjugates provide greater interfacial strength and emulsion stability. These insights support the development of next-generation prebiotic–protein conjugates for functional food emulsions, nutraceutical delivery systems, and gut-health-promoting formulations.

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[1114] Influence of pH on adsorption kinetics and interfacial rheology at the oil-water interface of *Chlorella* vs *Spirulina* Proteins: Implications for encapsulating microalgal oil

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Microalgal proteins offer promising functionality for structuring oil–water interfaces, yet their interfacial behavior under varying pH conditions—and the implications for encapsulating microalgal-oil bioactives—remain largely unexplored. This study investigates the adsorption kinetics and interfacial rheology of protein isolates from *Chlorella vulgaris* and *Arthrospira platensis* (Spirulina) across a range of pH values relevant to food and nutraceutical applications. Interfacial tension measurements were used to quantify dynamic adsorption and film formation, while dilatational interfacial rheology provided insight into interfacial viscoelasticity and network development.
Marked differences were observed between the two protein isolates in their pH-dependent interfacial behavior. *Chlorella* proteins exhibited faster adsorption kinetics at neutral and alkaline pH, forming interfacial layers with relatively rapid reduction of interfacial tension. In contrast, *Spirulina* proteins generated more elastic and structured interfacial films, particularly near their isoelectric region, indicating stronger intermolecular interactions and enhanced film rigidity. These differences were reflected in emulsion formation and stability when encapsulating microalgal oil rich in lipophilic bioactives. Emulsions stabilized with *Spirulina* proteins showed improved oxidative protection and retention of bioactives, whereas *Chlorella*-based emulsions offered more efficient initial encapsulation due to their faster interfacial adsorption.
Overall, the results demonstrate that pH critically modulates the interfacial assembly and functional performance of microalgal proteins, influencing both droplet stabilization mechanisms and the efficiency of microalgal-oil encapsulation. These findings advance the understanding of microalgal proteins as natural emulsifiers and highlight their potential for the design of sustainable delivery systems for lipophilic bioactive compounds.

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[1116] Food-grade polyelectrolyte complex o/w emulsion microneedles enabling dual nutrient co-delivery for the patch food concept

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Hydrocolloids are emerging as multifunctional materials for next-generation food, nutrition, and health applications. However, the simultaneous delivery of hydrophilic and lipophilic nutrients within a single hydrocolloid matrix remains a fundamental challenge due to mutual incompatibility, limited mechanical strength and uncontrolled release. In this study, we developed an O/W emulsion-based dissolving microneedle (DMN) system, stabilized by food-grade polyelectrolyte complexes (PEC), for the dual transdermal delivery of ascorbic acid (AA) and lycopene (LY), supporting a novel ‘Patch-Food’ concept.

A dual-network hydrocolloid matrix was designed by combining cationic chitosan (CS) and anionic hyaluronic acid (HA), forming a PEC network acting as physical crosslinking points within the PVA/PVP continuous phase. This system enabled stable co-loading of the AA-loaded aqueous phase (PVA/PVP/HA/CS) and the LY-encapsulated oil phase at a 1:9 (O/W) ratio (pH 5). The effect of CS concentration (0–2%) on the system was investigated in depth through rheological and microstructural analyses. Furthermore, the mechanical properties TA, XRD, dissolution characteristics, *in vitro* release patterns and DPPH antioxidant activity of the fabricated DMNs were comprehensively analyzed.

Rheological analysis revealed a unique non-linear viscosity behavior (0% > 2% > 1%) dependent on CS concentration. Microscopy visually demonstrated this mechanism: 1% CS induced a 'collapse' of the existing network via PEC formation (a ball-bearing effect), drastically lowering viscosity. In contrast, 2% CS caused 'bridging' between particles, leading to aggregation (intermediate viscosity). This structural optimization led to a significant improvement in mechanical strength, doubling it from ~20 N to ~40 N and ensuring reliable skin insertion. CS-induced bridging also enhanced emulsion stability.

DMN dissolution was tunable by CS concentration: low-CS formulations exhibited rapid dissolution (~15 min), whereas PEC-reinforced DMNs dissolved over 120 minutes, enabling sustained release. *In vitro* studies confirmed a synchronized yet distinct profile: rapid AA diffusion and gradual LY release. XRD analysis confirmed both nutrients were stably dispersed in an amorphous state.

This study demonstrates that bioactive polysaccharides (CS/HA) are not mere additives but key functional materials actively controlling the rheological properties and

microstructure of the O/W emulsion. Adjusting CS concentration alone allowed stability, mechanical strength and release rate to be programmed from initial burst to sustained. This approach presents high potential as a next-generation personalized nutrition delivery system, realizing the "Patch-Food" concept.

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1119 Interface-governed physical aging in multilayer gelatin films

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Gelatin has remarkable ability to form thin films which are characterized by random molecular arrangements in a glassy state. However, when stored below the glass transition temperature, the molecular chains form helical structures (microcrystals), leading to physical aging as they shift toward a more stable state. Despite microcrystal formation, this aging negatively affects the film's strength and flexibility. To address this, we explored delaying microcrystal formation by stacking gelatin films with different isoionic points: Type A (acidic) and Type B (alkaline), creating two to five-layer structures. Each film was prepared as a 7.5% (w/v) solution with 20% glycerin added relative to gelatin weight. The films were dried at 37°C, alternately stacked, and heat-pressed to form multilayer samples. These were stored at 30°C and 50% relative humidity for 50 days, with periodic monitoring.

Physical aging was assessed through enthalpy recovery measurements using differential scanning calorimetry (DSC) and tensile tests to evaluate mechanical strength changes due to lamination.

DSC results showed that both Type A and Type B monolayers experienced gradual enthalpy recovery from day 0 to 20, a sharp increase from day 20 to 30, and deceleration approaching saturation by day 50. Type A exhibited higher recovery than Type B. In laminated films, enthalpy recovery did not follow a simple linear average of Type A and B. Instead, it declined depending on layer configuration and sequence. This irregularity is attributed to electrostatic interactions at the Type A–B interface, altering free volume distribution and helix formation, and leading to hydrogen bond reorganization and water redistribution.

Tensile tests on films with four or more layers revealed embrittlement initially, followed by ductility recovery over time. This dual-stage behavior likely results from initial free volume reduction and heterogeneous helix nucleation near interfaces, followed by the formation of

a tougher, more homogeneous network through helix reorganization, interface restructuring, and water redistribution.

To better understand these thermal and mechanical changes, dynamic analyses such as dielectric relaxation measurements are needed to monitor the gelatin molecular chains' motion.

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[1120] Synergistic stabilization of W/O high internal phase emulsions (HIPEs) using a PGPR/HPMC hybrid interface within oleogel network

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This study developed a novel triple hybrid stabilization system combining minimal PGPR, hydroxypropyl methylcellulose (HPMC), and beeswax (BW) to overcome the inherent physical instability of W/O high internal phase emulsions (HIPEs). W/O HIPEs with a 75% internal phase were prepared using PGPR alone, PGPR+HPMC, PGPR+BW, and PGPR+HPMC+BW combinations, and their stability was comparatively analyzed. Synergistic effects among these components were evaluated through rheological measurements, microstructure analysis using CLSM, and centrifugal stability testing. Results showed that the PGPR-only system exhibited significant phase separation within 24 hours and low stability. The dual systems, PGPR+HPMC or PGPR+BW, demonstrated improved stability compared to the single system, but some droplet coalescence was still observed during high-speed centrifugation. Conversely, the triple system (PGPR+HPMC+BW) using all three components exhibited the highest stability, showing significantly enhanced storage modulus (G') and yield stress compared to the dual systems. CLSM analysis supported the proposed triple stabilization mechanism, where HPMC reinforces the interface from within the aqueous phase, and the BW crystal network forms in the oil phase to physically anchor the reinforced droplets. This triple system exhibited high resistance, maintaining most of its structure even under high-speed centrifugation. In conclusion, the synergistic combination of an HPMC-reinforced internal phase and the BW oleogel network is an effective strategy for producing food-grade W/O HIPEs with enhanced stability, which can be widely applied in the development of low-calorie fat substitutes and functional substance delivery systems.

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[1121] Natural lipid carriers: enhancing functional ingredient skin permeation through oleosome membrane properties control

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Purpose
Oleosomes are natural lipid droplets with strong potential as carriers for functional ingredients, yet their delivery and release mechanisms remain insufficiently understood. This study extracts hempseed oleosomes, loads with hydrophobic functional ingredients, and elucidates how membrane properties regulate ingredient release in an *in vitro* skin permeation model.

Methods
Oleosomes were extracted and purified from hempseeds using an aqueous extraction method. Hydrophobic ingredients were encapsulated via a co-solvent method and evaluated using a Franz diffusion cell to assess *in vitro* skin permeation.

Results
Encapsulation efficiencies exceeded 90 wt% across different adding concentrations. In the Franz diffusion cell assay, both release and skin accumulation of functional ingredients increased with higher encapsulation levels. Modulating oleosome membrane properties altered the intermolecular interactions between proteins and phospholipids, thereby facilitating ingredient release and permeation.

Conclusions

This work demonstrates the potential of hempseed oleosomes as natural carriers for transdermal delivery. Hydrophobic functional ingredients can be efficiently encapsulated while oleosomes maintaining high structural integrity. Skin permeation is strongly dependent on loading concentration, and membrane property modulation provides an effective strategy to tune intermolecular interactions, release profiles, and transdermal transport. These findings clarify the mechanistic role of membrane properties in release kinetics and bioavailability, offering a natural alternative to synthetic emulsifiers and over-processing.

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[1124] Uncovering the Role of Floridean Starch in Furcellaran Gelation

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Red algae store carbon as floridean starch, a cytosolic branched α-linked glucose polymer (Fig. 1). As an intermediate between amylopectin and glycogen—often described as "semi-amylopectin" [1, 2]. The term floridean starch originates from the red algal class Florideophyceae, where this storage glucan is abundant, though it also occurs in glaucophytes and other rhodophytes as a primary sink for carbon fixation. In species such as *Furcellaria lumbricalis*, floridean starch accumulates in discrete cytoplasmic granules and can occupy a substantial proportion of the cell volume, distinguishing it structurally and spatially from the plastid-based starch of green plants [1, 2].

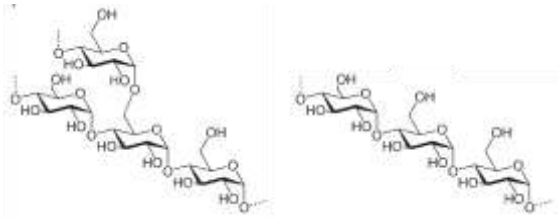

Figure 1. An example of glucose α-1-4 (A and B) and α-1-6 branching (A).

Floridean starch can account for up to 20% of the algal dry weight, and during carrageenan extraction it is commonly removed to prevent interference with the gelling performance of the sulfated galactans [3]. In this study, floridean starch isolated from *F. lumbricalis* using aqueous extraction is compared to crude extracts, purified furcellaran (β/κ-carrageenan), and their reconstructed blends. We evaluated the specific influence of floridean starch on carrageenan gelation behaviour and mechanical properties.

Floridean starch properties are characterized using spectrophotometric analysis of the starch–iodine complex and differential scanning calorimetry (DSC). The degree of branching was assessed by ^{1}H-NMR to quantify the relative proportions of α-1,4 and α-1,6 linkages, the monosaccharide composition was determined using HPAEC-PAD and the molecular weights by HPLC-SEC.

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[1125] Impact of freezing-induced glass and crystalline states in carbohydrate-protein complexes on the survival rate of probiotics

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Higher glass transition temperatures (Tg) reduce molecular mobility in dried matrices, and Tg elevation has emerged as an effective approach for improving microbial stability. Therefore, this study examined how crystalline and amorphous structures influence the survival rate of *Leuconostoc mesenteroides* throughout freezing, freeze-drying, and storage. Accordingly, whey protein isolate (WPI) was used as a protein matrix, and inulin, lactose were chosen as carbohydrate components. Each carbohydrate was individually combined with WPI. These formulations were mixed with *Leuconostoc mesenteroides* and subjected to either one-step rapid freezing at -100°C or two-step freezing at -20°C followed by -100°C prior to freeze-drying. One-step rapid freezing produced amorphous samples and two-step freezing promoted crystallization. To characterize the structural differences, appearance, X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FTIR), and differential scanning calorimetry (DSC) were performed. In addition, the survival rate during 30 days of storage was evaluated by comparing viable cell counts with those of an unfrozen control. XRD analysis confirmed the presence of crystalline structures in two-step frozen samples, whereas rapid freezing generated peak-free amorphous patterns. These structural differences were also reflected in appearance, with amorphous samples exhibiting a glossier surface than crystalline samples. FTIR confirmed these distinctions: amorphous samples exhibited broadened O–H stretching bands (3200–3500 cm^{-1}) and less-defined carbohydrate features, whereas crystalline samples showed sharp peaks indicating ordered structures. DSC demonstrated that inulin systems had higher Tg than lactose systems, and amorphous matrices consistently showed higher Tg than crystalline ones. Survival results also reflected these structural differences, with inulin formulations showing higher survival rate in amorphous glassy

matrices (94% initially; 87% after 30 days) than in crystalline samples (75% initially; 66% 30 days). In lactose-based samples, amorphous matrices also maintained high survival rate (92% initially; 87% after 30 days), while crystalline matrices showed low rate (72% initially; 60% 30 days). These findings demonstrate that freezing-induced physical state and carbohydrate type determined probiotic stability, with inulin-containing amorphous matrices offering superior long-term protection.

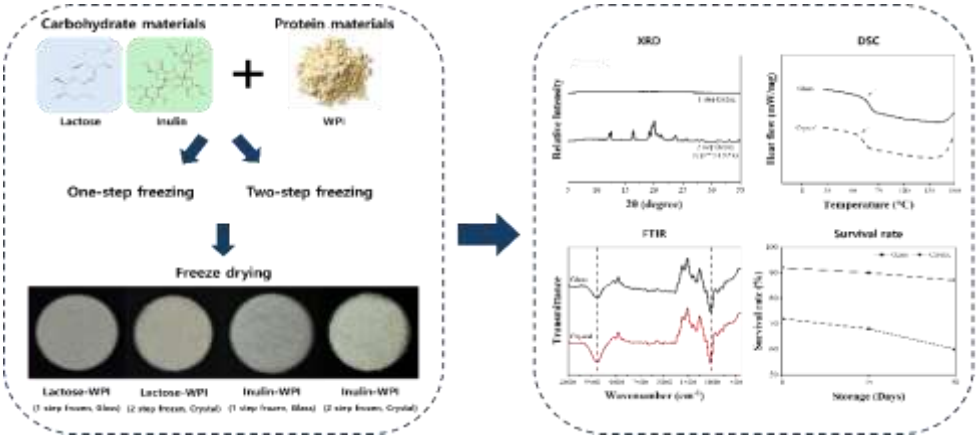

Fig.1. Overview of this study.

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[1126] Exploring algae-based hydrocolloids extracts as coatings for edible packaging solutions

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Single-use plastic packaging must be eliminated, as its impact on planetary health is huge, since it does not degrade and soon turns into microplastic particles. This has led to the development of edible and biodegradable packaging alternatives. This study presents an integrated edible packaging system that combines microalgae- and macroalgae-based components using 3D food printing technology. Edible cups were formulated using *Chlorella vulgaris* biomass and 3D-printed with a helical ridge design to increase their surface area, enhance adhesion of subsequent edible hydrocolloid coatings and reduce permeability.
Aqueous extracts of hydrocolloids from *Chondrus crispus* were used to develop the coatings, either as a control or enriched with lipid extracts or glycerol. This strategy

enables the principles of 'Clean Label' to be maintained while hydrocolloids are still used as crucial ingredients.
Chemical analyses were conducted to determine the antioxidant potential (FRAP, DPPH and ABTS assays). Mechanical properties, water vapor permeability, and light barrier properties were also evaluated for the edible films.
The results showed that incorporating *C. vulgaris* added structure to the 3D 'ink', resulting in improved extrusion and better shape fidelity. This was crucial in enabling the accurate printing of the ridged cup structure. This design retained significantly more coating — over 170% more than the smooth-walled control cup. Not only did the *C. crispus* hydrocolloid coatings add a protective barrier, improving UV resistance, mechanical integrity and water permeability control, they also contributed additional antioxidant activity to the final product.
The printed matrix and the hydrocolloid-based surface coating worked synergistically to produce fully edible, nutrient-rich, functional, clean-label packaging. This work demonstrates how formulation and design can be optimised together to develop sustainable, completely biodegradable, clean-label packaging with enhanced structural and nutritional performance.

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1127 Influence of saccharide chain lengths on the glass transition temperature and water sorption of amorphous corn starch matrices

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This study investigated the effect of saccharides with different chain lengths on the glass transition temperature (Tg) and water sorption behavior of corn starch. Glucose (monosaccharide), sucrose (disaccharide), raffinose (trisaccharide), and stachyose (tetrasaccharide) were selected. Corn starch and saccharide were mixed at 1:1 (w/w) ratio and dispersed in deionized water to obtain a 5% (w/v) suspension. The suspensions were heated at 95°C for 1 h, cooled to 25°C, frozen at -100°C, and freeze-dried. Optical microscopy analysis revealed non–uniformly shaped fragments and sheet–like structures, indicating the destruction of the crystalline structure. X-ray diffraction confirmed the amorphous structure of gelatinized starch. Water sorption behavior of corn starch-saccharide matrices was examined using the Guggenheim-Anderson-de Boer (GAB) model. The Tg of each sample was determined by differential scanning calorimetry. The

effect of water content on the Tg for samples was analyzed using the Gordon-Taylor (GT) equation. Longer saccharide chain lengths were associated with a decrease in monolayer water contents and an increase in the C constant, indicating stronger monolayer binding energy compared with bulk and reduction of water mobility at the initial sorption sites. Such behavior reflects a matrix with restricted water mobility, leading to enhanced stability of the amorphous starch-saccharide systems. GT analysis revealed that systems with higher k values exhibited greater Tg sensitivity to water, reflecting enhanced water-plasticization during hydration. In contrast to the general pattern, raffinose presented a low C value while displaying a high k value, implying that hydration promotes extensive free-volume increase and thereby amplifies the Tg response to water. These combined results demonstrate that dual role of saccharide chain length in controlling both dry-state mobility and water-induced destabilization of starch-based amorphous matrices. Such insights are essential for predicting the stability of starch-based powdered products and guiding the design of starch-based products with improved functional properties.

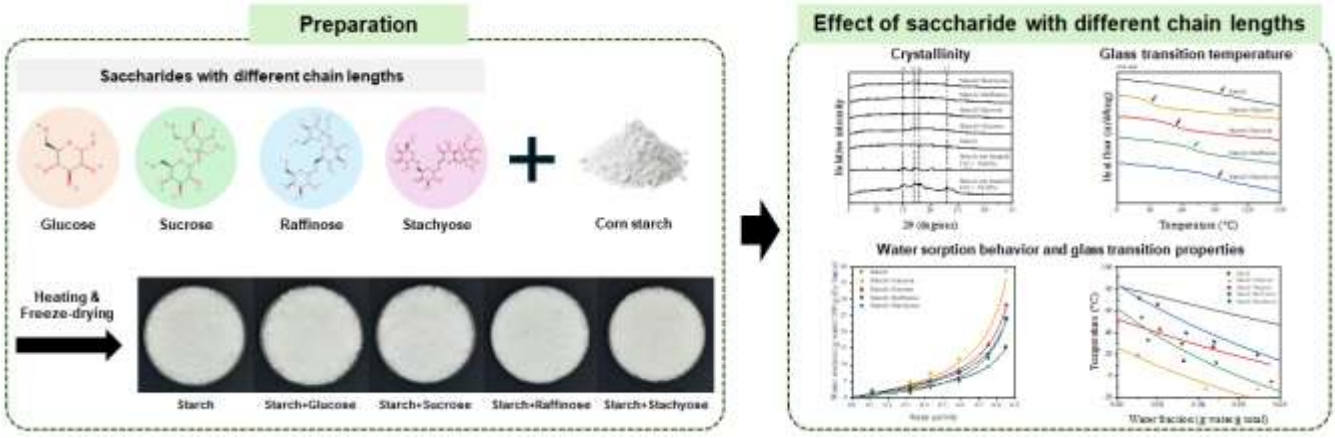
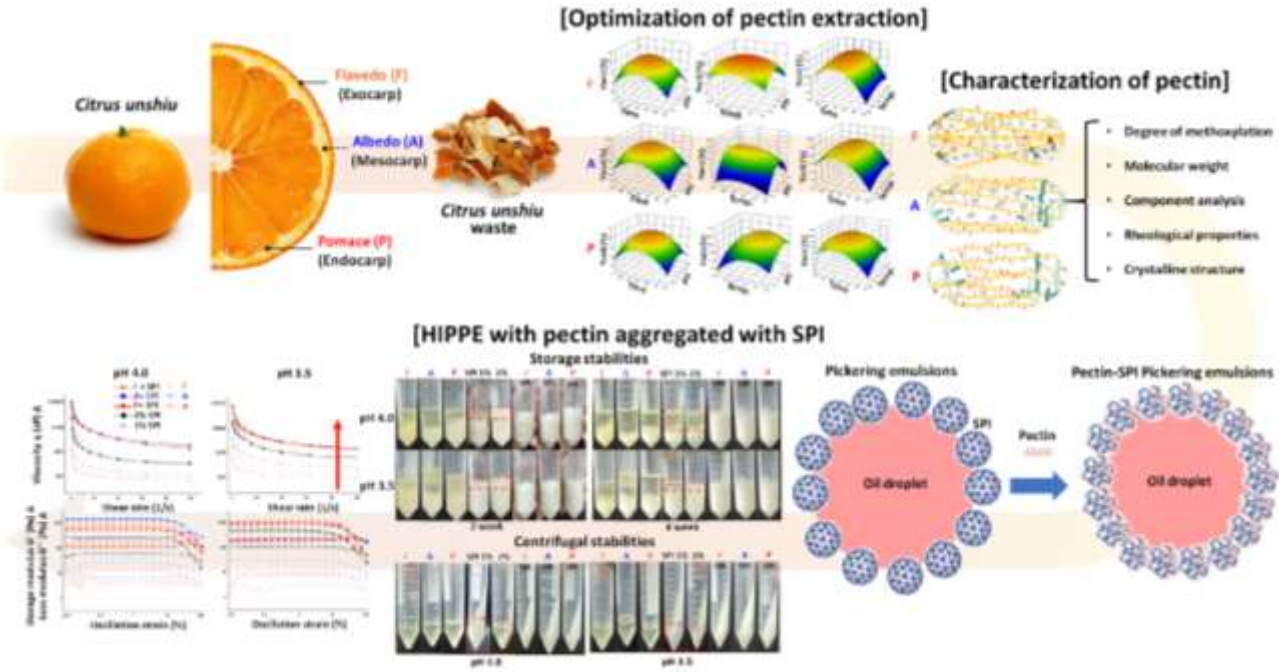


Fig. 1. Hypothesis of this study. Influence of saccharide chain length on the glass transition temperature and water sorption behavior of starch systems



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[1128] Effect of the molecular structure of the gelling agent on the gelation behavior of xyloglucan

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Xyloglucan extracted from tamarind seeds is a complex, branched polysaccharide composed of a cellulosic backbone substituted at the O6 position with side chains of α-1,6-linked xyloses, 1,2-linked β-galactoses, and occasionally α-1,2-linked fucoses. Xyloglucan has significant potential for commercial applications, particularly in the pharmaceutical and food industries, where it can be used to control drug release and modify texture. Although this polymer does not form a gel on its own, it can exhibit gelation behavior when mixed with certain small molecules, such as iodine, Congo red, Eriochrome Black T, and gallate analogs. In the present study, the gelation behavior of xyloglucan in the presence of various molecules was investigated to elucidate the underlying gelation mechanism and to identify the molecular structures responsible for inducing xyloglucan gelation.

Initially, the gelation behavior of xyloglucan was examined using gallic acid (GA) as a gelling agent. A sol–gel transition was observed in a 3.0 wt% xyloglucan solution. The sol–gel transition temperature (gel-melting temperature) was determined by the falling-ball method. Xyloglucan and GA were fully dissolved in water in a 8-mm glass tube and allowed to gel at 4 °C. A steel ball was placed on top of the gel. Upon heating, the gel eventually melted and converted to a sol, at which point the steel ball began to move downward. The temperature at which the ball started to move was defined as the gel-melting temperature.

Figure 1 shows the effect of GA concentration and solution pH on the gel-melting temperature. The gel-melting temperature increased with an increase in GA concentration, reaching approximately 60 °C. Moreover, the gel-melting temperature was higher at lower pH values (pH 4.0). Since the pKa of GA is about 4.5, the fraction of protonated acid species is high at pH 4.0, These results indicate that protonation of the carboxyl group plays a crucial role in controlling gelation behavior. In addition, the molecular structure of the gelling agent is critical for inducing xyloglucan gelation. Replacement of the aromatic ring in GA with an aliphatic chain of the same carbon number resulted in weakened gel strength. Furthermore, the relative positions of the carboxyl and hydroxyl groups were found to be key factors in determining the sol–gel transition temperature of xyloglucan.

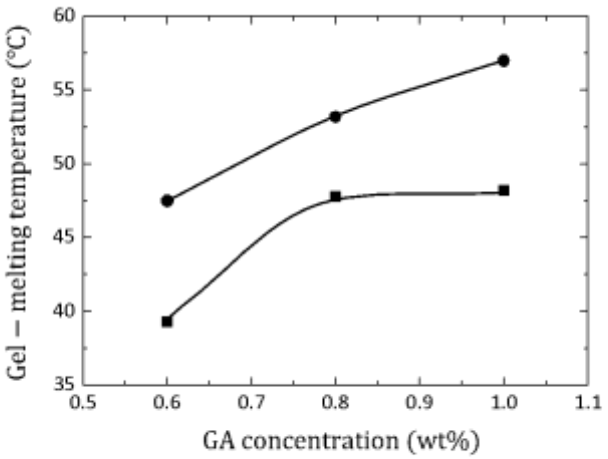

Figure 1. Effect of GA concentraion and solution pH on gel – melting temperarure.
The solution pH is (●)4.0 and (■) 5.0.

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1129 Development of low-glycaemic white bread by substituting Thai local blend flours for optimization of texture and sensory quality.

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Bread is a staple food typically prepared with white flour which has a high glycemic index, meaning that it causes a rapid increase in postprandial blood glucose levels. This

study aimed to develop a low-glycaemic index (low-GI) bread as a healthier alternative product that meets consumers expectations. This was achieved by substituting wheat flour with Thai local flours, including white bean flour, Job's tears flour and mung bean flour blended using a mixture design approach to optimize the flour composition, while rice flour and corn flour were fixed at 1:3 ratio as part of the base formulation. To improve dough structure and overcome the crumbliness observed in the preliminary non-pre-gelatinization trials, the flour blends were further modified using a Tangzhong-based pre-gelatinization technique prior to incorporation into the bread dough. Two major groups of properties were evaluated: flour properties and bread quality attributes. Flour properties included pasting characteristics (RVA), water absorption index (WAI), water solubility index (WSI), swelling power (SP), and water holding capacity (WHC), assessed for both single flours and blended formulations. The results showed the difference flour properties indicating variations in gel formation. Mung bean flour presented a high peak viscosity, final viscosity, and setback (3460 $\pm$ 16.82, 5090 $\pm$ 69.46 and 2776.33 $\pm$ 19.55) that indicated the gelatinized starch forms a highly viscous, firm and stable gels but can increase hardness in bread if used at high levels. Corn flour exhibited the highest WAI (9.28 $\pm$ 0.25) and SP (9.41$\pm$0.25), indicating strong granular expansion; however, the RVA result showed moderate final viscosity. Its gel tends to be firm but not very cohesive. Furthermore, rice flour demonstrated high final viscosity (4112 $\pm$ 31.05) and setback (2406 $\pm$ 23.06) indicating that rice starch forms a stiff and brittle gel. Conversely, white bean and Job's tears flours showed the low WAI and SP (7.87 $\pm$ 0.23 and 5.49 $\pm$ 0.56) forming weaker gels. These differences highlight the need to blend flours to balance viscosity, water interaction, and gel strength for producing bread with optimal texture and flavor. Bread quality was analyzed through texture profile analysis (TPA), loaf volume, specific volume, colour measurement, descriptive sensory analysis, and glycaemic index assessment. It was found that the addition of a pre-gelatinized blend flour, consisting of rice flour, corn flour, white bean flour, Job's tears, and mung bean at 10%, 30%, 15%, 15%, and 30%, substituting 50% of wheat flour, produced bread with enhanced texture and flavor that were acceptable by consumers. The findings provide insights into how Thai local flours and pre-gelatinization interact to influence the functional, structural, and sensory attributes of low-GI bread, supporting their potential use in developing healthier bakery products with improved consumer acceptability.

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[1133] Sustainable Production of Cellulose from Palm Tree Biomass

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In this study, local palm tree (Sukkary) cellulose has been extracted using heating and chemical pretreatment methods. To remove lignin and hemicellulose, the date palm tree biomass (fronds) was soaked in a 2% sodium hydroxide (NaOH) solution for two hours, with stirring and heating at 80°C. The treated material was thoroughly washed with distilled water to neutralize and remove residual chemicals. A black solution resulted from the removal of lignin and hemicellulose. Bleaching was applied using sodium hypochlorite as a bleaching agent to further purify the cellulose and achieve the desired whiteness. Final washing was performed by rinsing the material again to ensure that all chemicals were removed. Drying the cellulose in an oven at 45°C for three hours to remove moisture from the isolated cellulose resulted in a dry, white fibrous form. The achieved cellulose yield was 39.2-45.3%. FTIR spectroscopy and XRD analysis were used to evaluate the purity and structural integrity of the produced cellulose. The potential applications of the extracted cellulose including the health benefits of cellulose and its role in dietary applications and the cellulose-based bioplastic for food packaging. This initiative aligns with global efforts to reduce the environmental impacts of agricultural waste and supports the transition toward renewable resources.

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1144 Structural Characteristics and Temperature-Responsive Sequential Release Behavior of Dual-Encapsulated Flavor Oil–Seasoning Biopolymer Complexes

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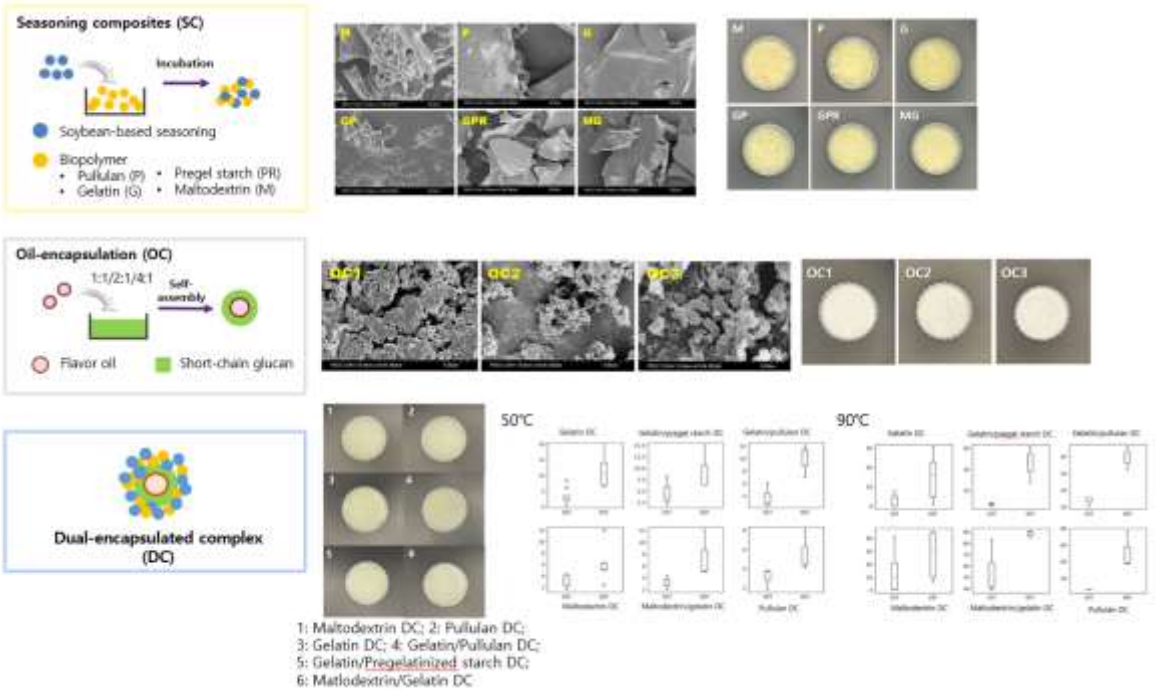
This study aimed to develop a novel biopolymer-based complex capable of dual encapsulation and temperature-responsive sequential release of flavor oils and seasoning components for food formulation applications. Hydrophilic biopolymers—pullulan, gelatin, pregelatinized starch, and maltodextrin—were used to formulate composites carrying soybean-based seasoning components (seasoning composites, SC). Separately, hydrophobic flavor oils were encapsulated using self-assembled short-chain glucan (oil-encapsulation composites, OC) and subsequently integrated with the hydrophilic matrices to form dual-encapsulated complexes (DC). Physicochemical properties, including appearance, structural features, and morphology, were characterized, and release behavior was evaluated at 50 and 90℃ using GC–MS to determine temperature-

responsive and sequential release performance. SEM analysis revealed that each SC exhibited distinct microstructural characteristics depending on interactions among the constituent biopolymers. The maltodextrin SC displayed a smooth and dense surface, likely due to rapid solidification and pore formation during freeze-drying, whereas the pullulan SC showed a compact yet flexible network with partial particle aggregation. In contrast, the gelatin SC and gelatin/pullulan SC exhibited irregular and porous structures, attributable to protein–polysaccharide interactions that promoted cross-linking and pore development during drying. The OC, prepared by incorporating flavor oils with varying ratios of starch-derived ingredients, also exhibited pronounced morphological differences. The 1:1 formulation exhibited a relatively smooth surface attributable to excess oil loading, whereas increasing the proportion of starch-derived materials produced rougher surfaces with noticeable aggregated domains, suggesting that biopolymer content markedly affected oil dispersion and encapsulation efficiency. For temperature-responsive evaluation, core materials containing standard compounds were incorporated into the DC designed to disassemble at either ≥50℃ or ≥90℃, and fold changes relative to 30℃ were calculated. At 50℃, most formulations displayed significant increases in release, although the maltodextrin–oil DC exhibited unstable behavior, whereas the gelatin–oil and gelatin/pullulan–oil DC showed superior performance. At 90℃, release increased progressively, and formulations such as the gelatin/pregelatinized starch–oil, gelatin/pullulan–oil, gelatin–oil, and pullulan–oil DC met the intended design criteria by showing minimal changes at 50℃ but pronounced increases at 90℃. Overall, the developed dual-encapsulated flavor oil–seasoning biopolymer complexes represent a promising strategy for engineering smart seasoning systems capable of temperature-triggered and stepwise release of multiple functional components. These findings underscore the potential of biopolymer-based materials as clean-label platforms for the controlled delivery of flavor constituents in next-generation food processing and formulation.



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[1153] Development of gluten-free pasta products using Thai local flour

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Pasta is a popular food consumed worldwide; however, wheat flour is its main ingredient, which poses dietary limitations for individuals with celiac disease. Celiac disease, also known as gluten-sensitive enteropathy, is increasingly being diagnosed, with a prevalence ranging from 0.7% to 2.9% of the global population. This disease is an autoimmune enteropathy caused by gluten intolerance. Gluten is a protein found in wheat, barley, and rye. This research was aimed to develop gluten-free pasta products by using Thai local flour including rice flour, corn flour, tapioca flour, and mung bean flour. Each flour was mixed with different proportions of rice flour (30%w/w and 40%w/w) and mung bean flour (25%w/w and 35%w/w). All flours and mixed flours were analyzed for gelation properties, which included water absorption index (WAI), water solubility index (WSI), swelling power (SP) and pasting properties, using the Rapid Viscosity Analysis (RVA) method. The mixed flour was pre-gelatinized and used to replace wheat flour at levels of

0%, 50%, and 100%. The mixture of Thai local flour will be kneaded to form dough and analyzed the texture of dough before extruding using Texture Profile Analysis (TPA) and after extruding using Tensile force analysis. The results showed that the WAI of corn flour was significantly highest, followed by mung bean flour, rice flour, tapioca flour, and wheat flour, with values of 10.20 ± 0.28 g/g, 9.15 ± 0.10 g/g, 8.58 ± 0.35 g/g, 7.73 ± 0.31 g/g, and 7.67 ± 0.05 g/g, respectively. The SP was consistent with WAI, in which corn flour exhibited significantly highest followed by mung bean flour and rice flour, with values of 10.33 ± 0.29 g/g, 9.32 ± 0.10 g/g and 8.76 ± 0.35 g/g respectively. In contrast, wheat flour showed the highest WSI, demonstrating that its internal components exhibit greater water solubility. The high WAI and SP values of the flour indicate that Thai local flour performs well in gel formation, making it suitable as a substitute for wheat flour. The Thai local flour mixture provides the most suitable texture and favorable sensory properties of fettuccini by wheat flour substitution at 50%, 0%, and 100%, respectively. At a 50% substitution level, the fettuccine exhibited a yellow color with a tender and elastic texture comparable to conventional pasta. At 0% substitution, the fettuccine were yellow with a firm, chewy, al dente texture. At 100% substitution, the fettuccine were translucent white and possessed a firm, sticky, and elastic texture. It can be a substitute for wheat flour at 100% based on consumer acceptance. The replacement of wheat flour with Thai local flour can favorably be used in gluten-free fettuccine formulation.

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1154 Effects of saccharides and polyphenols in aqueous extract of pitaya on the encapsulation of *Lactiplantibacillus plantarum*

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Pitaya (*Hylocereus* spp.) is rich in polyphenols and saccharides with health benefits, such as antioxidant and anti-inflammatory activities, and varieties can be divided into red pitaya and white pitaya based on the color of the fruit flesh. Lactic acid bacteria (LAB) as probiotics are 'live microorganisms' on the benefits for host by improving the balance of intestinal microbial flora, and have been confirmed to have the beneficial health effects including inhibition of intestinal pathogens, modulation of the immunity system, reduction of cholesterol, and prevention of cancer. The aim of this study was to investigate the high-efficiency green extraction of bioactive compounds from whole fruit of pitaya by ultrasound (US), and effects of nutrient from aqueous extract of pitaya and US on the encapsulation of LAB. The lactic acid bacteria used in this study was *Lactiplantibacillus plantarum* FEL112, which was isolated in our laboratory. Different types of cell suspension of *L. plantarum* FEL112 with carboxymethyl cellulose (CMC), inulin, or aqueous extract of pitaya were used in the encapsulation of bacteria with capsules prepared from sodium alginate concentrations using excess calcium chloride by the extrusion method. The

effects of various US durations, sodium alginate concentrations, and cell suspension liquids on the growth and β-glucosidase activity of encapsulated *L. plantarum* FEL112 were explored. The main saccharides in aqueous extract of pitaya were fructose and glucose, and the fructose contents in the aqueous extract of pitaya were between 0.2 - 0.3 g/g-extract. Furthermore, the glucose content is higher than the fructose content in aqueous extract of red pitaya or white pitaya, showing that saccharides are present in aqueous extract of pitaya to provide the carbon source for *L. plantarum* FEL112. For polyphenols, the content of chlorogenic acid was higher in the aqueous extract of white pitaya, being 7 times of that in the aqueous extract of red pitaya. The viable cell counts of the encapsulated bacteria by using inulin were 1.05 times higher than that by using CMC; however, the viable cell counts of the encapsulated bacteria by using CMC and aqueous extract of pitaya were 1.02 times higher than that by using only CMC, showing that aqueous extract of pitaya could promote the growth of *L. plantarum* FEL112 in the encapsulated state. For the bile salt tolerance, the survival for encapsulated bacteria by using CMC were higher than that using inulin in the simulated bile condition at longer time; however, regardless of whether aqueous extracts of pitaya were added, there was no significant difference in the survival for encapsulated bacteria with CMC. Besides, using CMC with aqueous extract of pitaya could greatly improve the survival for encapsulated bacteria under the simulated gastric juice condition. It could be concluded that the aqueous extract of pitaya was able to effectively enhance the stability of LAB under encapsulation as well as the added-values of pitaya in the development of health foods.

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[1155] Enhancing Pickering emulsion stability through faba bean protein isolate-dual polyphenol complexation

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1. Introduction

Pickering emulsions stabilized by plant derived particles align with clean label demands yet faba bean protein isolate (FBPI) often shows limited interfacial performance due to low solubility and compact globular structure. Non covalent interactions with polyphenols can modulate protein conformation but the cooperative effects of dual polyphenols remain insufficiently understood. This study aimed to enhance Pickering emulsion stability by forming FBPI complex nanoparticles with gallic acid (GA) as a small phenolic acid and rutin (RU) as a bulky flavonoid glycoside. The objective was to clarify how the complementary molecular characteristics of GA and RU generate cooperative structural and functional modulation of FBPI, thereby reshaping its molecular conformation, particle level properties, and interfacial assembly within a moderately unstable emulsion system with an oil volume fraction of 0.6.

2. Materials and Methods

Pretreated FBPI was mixed with GA at a fixed concentration followed by RU addition at increasing RU to GA ratios (0.0:1.0 ~ 1.0:1.0). Non covalent FBPI-RU/GA complex nanoparticles were characterized for particle size, ζ-potential, polyphenol binding content, solubility, exposed sulfhydryl (SH) and amino residues, and secondary structure. Pickering emulsions were prepared using canola oil and analyzed for droplet size ($D_{4,3}$), ζ-potential, interfacial protein adsorption, Turbiscan stability index (TSI), and microscopic features. Statistical differences were determined by analysis of variance with Duncan test at $p < 0.05$.

3. Results and Discussion

GA reduced FBPI particle size (Fig. 1A), increased solubility (Fig. 1C), and transformed disordered secondary structures into more ordered α-helix and β-sheet forms (Fig. 1F), improving dispersion and interfacial affinity. Incorporation of RU progressively increased polyphenol binding (Fig. 1B) and exposure of functional residues (Fig. 1D-E) while altering the balance between compaction and unfolding. At an intermediate RU to GA ratio of 0.4 to 1.0, nanoparticles exhibited high solubility, more negative surface charge, and a compact yet flexible secondary structure. These features enabled efficient migration to the oil water interface and formation of dense particulate films. The resulting emulsions showed smaller $D_{4,3}$, higher magnitude of ζ-potential (Fig. 1G), continuous fluorescent interfacial rings in microscopy (Fig. 1K), and the lowest TSI (Fig. 1I), reflecting strong resistance to coalescence and creaming. When RU proportion exceeded the optimal level, over unfolding and steric congestion occurred, reducing effective interfacial packing and weakening the particulate film. These effects were evident in larger $D_{4,3}$, decreased interfacial protein concentration, and increased TSI values. Collectively these findings indicate that Pickering stabilization depends on achieving an optimal balance in FBPI structure where GA driven compaction and RU driven unfolding act cooperatively rather than independently.

4. Conclusion

Dual polyphenol complexation offers a tunable route to engineer FBPI for clean label Pickering emulsions. A GA RU ratio of 0.4 to 1.0 produced nanoparticles forming cohesive and elastic interfacial films that markedly enhanced stability, whereas excessive RU

impaired assembly. This work clarifies how dual polyphenols modulate FBPI and provides a design framework for next generation plant-based stabilizers.

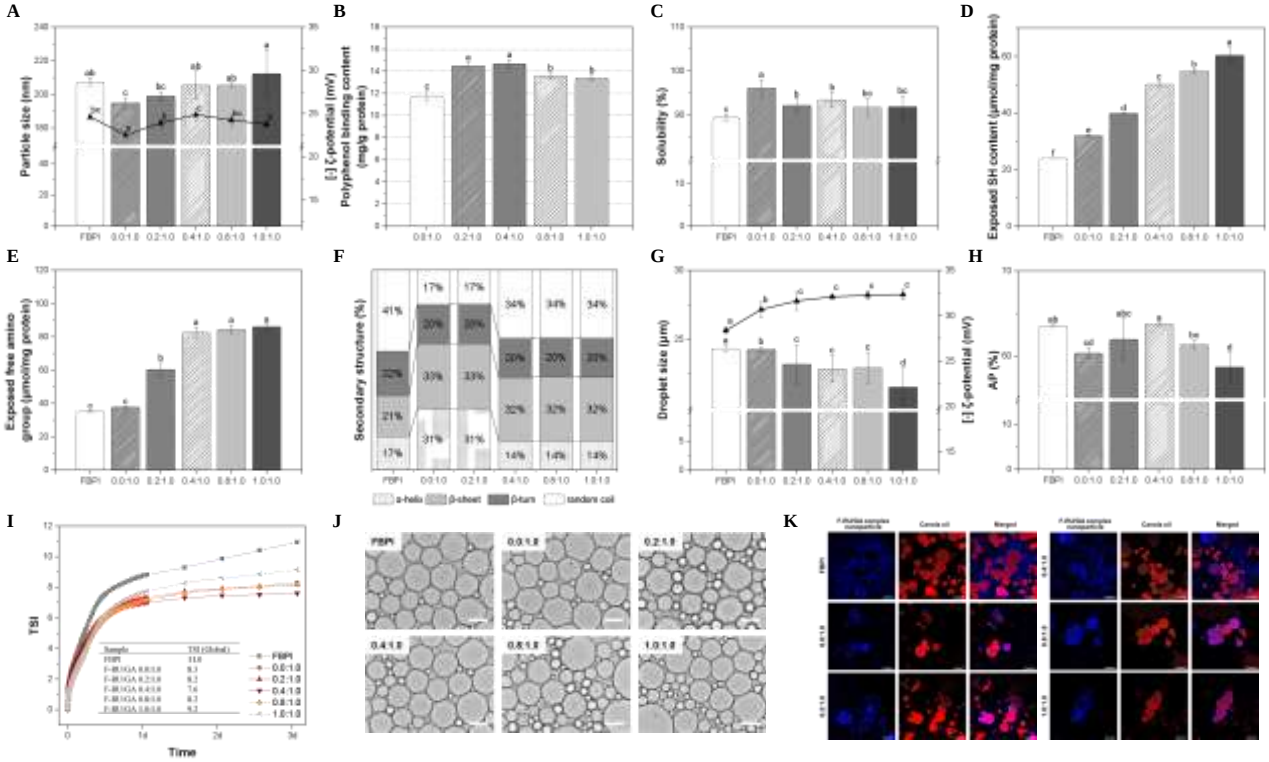

Fig. 1. Particle size and ζ-potential (A), polyphenol binding content (B), solubility (C), exposed SH group (D), exposed free amino group (E), and secondary structure of FBPI-RU/GA complex nanoparticle; droplet size and ζ-potential (G), adsorbed protein at the interface (H), Turbiscan stability index (I), optical microscopy images (J), and CLSM images of Pickering emulsions stabilized by FBPI-RU/GA complex nanoparticle. Scale bar=20 μm.

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1161 Probing the pH-induced reconfiguration of adsorbed gelatin onto a model colloidal interface

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Gelatin is a highly versatile hydrocolloid that plays a significant role in various applications as both a gelling and emulsifying agent in the food and pharmaceutical sectors. In the food industry, the mechanisms by which gelatin stabilizes emulsions have been extensively studied. Nonetheless, the dynamic changes, specifically the reconfiguration of the gelatin layer at the interface when pH changes occur in situ, such as during gastric transit, are frequently overlooked. In this study, we aimed to establish the relationship between dynamic pH changes and the structural reconfiguration of adsorbed gelatin on a model colloidal particle using microfluidics and optical tweezers. Microfluidics allows for variation in the solution environment, while optical tweezers enable the measurement of the hydrodynamic layer thickness of adsorbed gelatin in the presence of a flow field. When a 50 ppm gelatin solution prepared at pH 8.5 (isoelectric point) was injected, a temporal increase in the hydrodynamic layer thickness was observed (Fig. 1), indicating the adsorption of gelatin. Moreover, when a low pH solution was injected, an increase in the hydrodynamic layer thickness was demonstrated. This suggests a pronounced swelling of the gelatin layer at the interface, which is attributed to an increase in the net positive charge density, enhancing electrostatic repulsion between the adsorbed polymer chains. When the solution pH was changed back to high pH, a decrease back to the original adsorbed layer thickness was observed. Thus, this study provides important insights into the structural reconfiguration of the adsorbed gelatin onto a single colloidal interface.

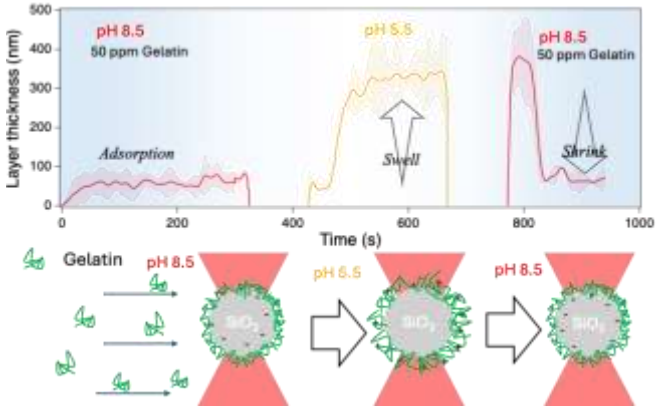

Fig. 1. Development of layer thickness during adsorption and changing pH conditions.

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[1162] Structural reinforcement of O/W bigels by incorporating soy protein isolate–gellan gum complex and beeswax: Enhancing 3D printing precision and freeze-thaw stability

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This study presents a novel strategy to enhance the freeze-thaw stability and printability of clean-label food inks by developing a complex-layer bigel (CLBG) system. In this system, soy protein isolate (SPI) and gellan gum (GEG) were used to form a complex to structure the aqueous phase, while beeswax (BW) was added to structure the oil phase through crystallization. A systematic comparative analysis between single-layer and complex-layer systems revealed that the complex-layer system, formed by electrostatic interactions and hydrogen bonding between SPI and GEG, established a robust interfacial network. This significantly improved viscoelastic properties compared to the single-layer system stabilized solely by protein. In addition, the conversion of free water into bound water was confirmed to greatly enhance the structural stability of the gel system. Notably, the dual-structuring strategy, combining aqueous phase structuring through the complex and oil phase structuring through the incorporation of beeswax (BW), further strengthened structural integrity through synergistic effects. This effectively mitigated structural damage caused by ice crystal formation during freezing, enabling the ink to stably maintain its inherent viscoelastic properties, water- and oil-holding capacities, and ζ-potential even after thawing. Consequently, color changes were suppressed to a level imperceptible to the naked eye ($\Delta E^* < 3$), despite undergoing freeze-thaw cycles. Furthermore, this system demonstrated outstanding 3D printing performance with high shape fidelity and deposition precision. Overall, the dual-structuring strategy integrating SPI-GEG complexes and wax presents a promising approach for designing freeze-thaw stable matrices for fat replacers in frozen foods and functional 3D printing applications.

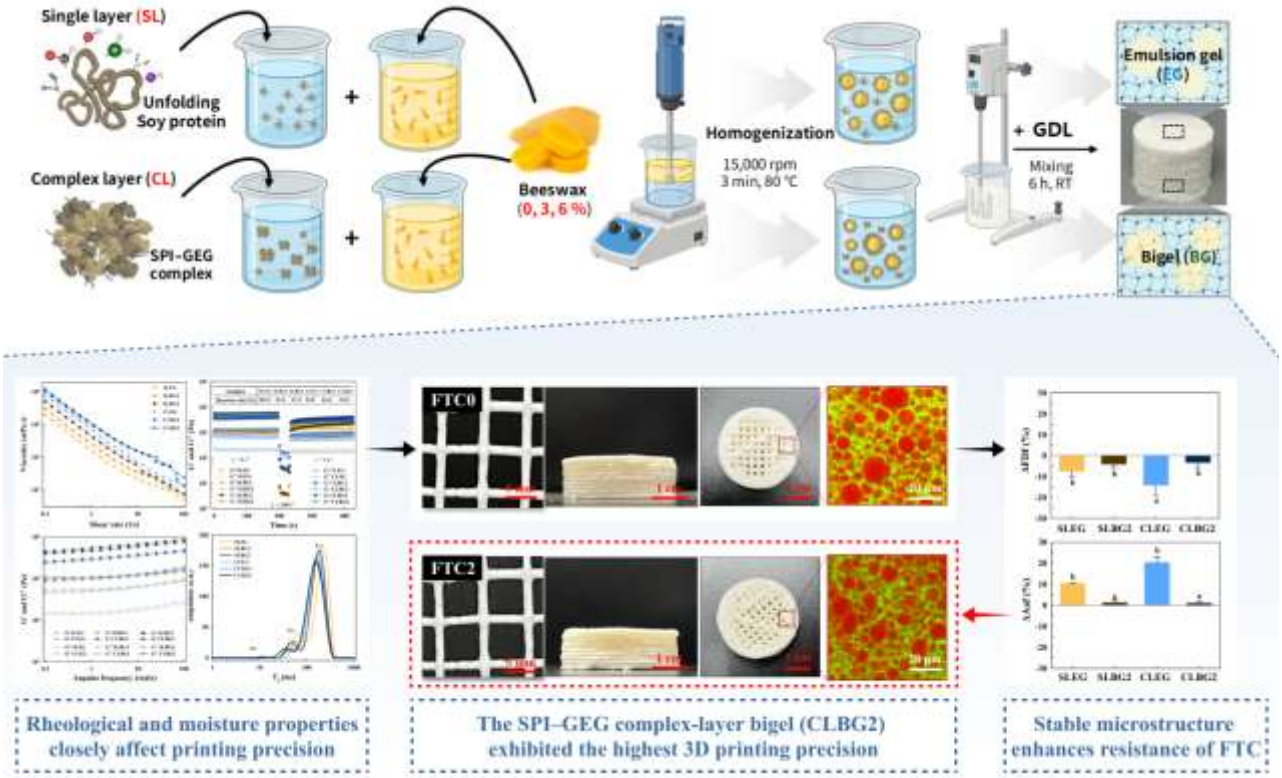

Figure 1. Fabrication process and evaluation framework for SPI-GEG complex-layer bigel (CLBG).

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1165 Rheology of bakery products bolus – Interaction with saliva and effects of shortening and whey protein isolate (WPI)

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Food oral processing is a key stage for safe swallowing, during which ingested foods are broken down through compression and shear by teeth and tongue and then mixed with saliva to form a cohesive bolus. In this study, we prepared three model bakery crackers: control that was made from wheat flour and water, a shortening-added sample, and a WPI-added sample. The three model crackers were fragmented into granules of ~1

mm for preparing artificial boluses by subsequently impregnating the granules with an amount of artificial saliva without amylase. The mechanical strength of the saliva-absorbed granules was evaluated by a penetration test, and the bolus rheology was characterized by strain-sweep and frequency-sweep measurements. The cracker samples with added fat exhibited a brittle and weak structure compared with the control, possibly due to the disruption of the gluten network by shortening. In contrast, the WPI-added samples showed greater mechanical strength than the control, which was attributed to the reinforcement of the protein network by WPI. As a result, the fat-added sample developed a sticky surface layer after absorbing 60% saliva, as the granule surface partially broke down. This sticky layer promoted strong inter-granular adhesion. However, the WPI-added samples showed weak adhesion due to lubrication by unabsorbed saliva, as their firm structure limited saliva penetration. With increasing saliva uptake, the mechanical strength of all samples decreased, while the overall strength remained in the order WPI-added > control > fat-added. The elastic modulus (G′) obtained from rheological measurements also decreased with saliva uptake in all samples. However, at 60% saliva, the fat-added samples showed a higher G′ than the control, despite their weaker individual granules, indicating that adhesive interactions between granules contributed to the bolus elasticity. In contrast, the WPI-added samples maintained higher elasticity than the other samples at all saliva levels, reflecting their inherently greater mechanical strength. In conclusion, our study clarified how the mechanical strength of the granules and the adhesion formed between them after saliva uptake influence bolus rheology. In addition, adjusting ingredient composition can modulate these rheological properties, providing useful insights for designing bakery products with improved texture and swallowability.

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[1168] Rheological Properties of Sulfated Agarans Extracted from Different *Gloiopeltis* Species

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Funoran is a sulfated red algal polysaccharide belonging to the broader class of agarans. Although it shares certain structural features with agarose and porphyran, funoran remains comparatively under-characterized, particularly regarding its cation-mediated

structural and functional properties. In this study, funoran fractions extracted from several *Gloiopeltis* species were systematically analyzed to elucidate their structural features and physicochemical behavior as hydrocolloids. The polymers were characterized using HPLC, FTIR, ^{1}H NMR spectroscopy, rheology, and wide-angle X-ray scattering (WAXS).
^{1}H NMR analysis confirmed the primary repeating unit of funoran as **G6S–LA** (β-D-galactose-6-sulfate–3,6-anhydro-α-L-galactose). WAXS revealed that the addition of only 20 mM $BaCl_2$ induced a distinct structural transformation, evidenced by the splitting of diffraction peaks into multiple reflections. This peak separation indicates increased chain ordering and tighter molecular packing, suggesting a strong and specific interaction between Ba^{2+} ions and funoran chains.
Ion-mediated changes were also evident in rheological measurements. At 300 mM $BaCl_2$, the storage modulus (G′) increased by more than an order of magnitude compared with the control (without Ba^{2+}), reflecting a substantial enhancement in gel strength and network cohesion. This dramatic rise in viscoelasticity is consistent with the formation of strong intermolecular cross-links and a denser polymer network mediated by divalent cations.
Overall, these findings provide important new insights into the structure–function relationships of funorans and demonstrate that divalent cation modulation—particularly through Ba^{2+}—offers a powerful strategy for tailoring the rheological and structural properties of sulfated agarans for cosmetic, biomedical, and other biotechnological hydrocolloid applications.

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[1170] LbL-driven Turing-like patterning in chitosan–gelatin films: morphological control and reaction–diffusion mechanisms

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Chitosan is a naturally derived biopolymer with excellent film-forming ability, biocompatibility, and antimicrobial activity. However, its single-layer films generally suffer from insufficient thermal stability and mechanical strength, limiting their practical applications. To enhance these properties, our laboratory has explored multilayer structures by layer-by-layer (LbL) assembly methods, alternately stacking chitosan and gelatin samples[1)]. During this process, we observed that films composed of three or more layers frequently exhibit distinctive stripe-like patterns. The dimensions of these stripes

ranged from approximately 0.5 mm to 2 mm, closely resembling the skin of mackerel. The origin and implications of these patterns, however, remain largely unexplored.

In this study, we first investigated the conditions that lead to the emergence of these patterns and conducted a systematic characterization of their morphology. Acid-processed gelatin, alkali-processed gelatin, and chitosan were used to prepare 7.5% (w/v) gelatin and 2.0% (w/v) chitosan solutions containing glycerol. Films were cast at 37 °C and laminated in alternating sequences to create three-layer samples, which were stored in sealed containers at 30 °C. Stripe patterns appeared in nearly all six possible combinations of chitosan–gelatin layer arrangements, with the geometric features varying depending on the stacking order.

A literature survey suggested that these structures resemble Turing patterns arising from reaction–diffusion dynamics. To verify this possibility, we implemented simulations using the Gray–Scott model in Python. The simulated patterns showed remarkable similarity to those observed experimentally, supporting this hypothesis.
Future work will employ differential scanning calorimetry to determine whether pattern formation affects the glass transition behavior, and small-angle X-ray scattering will be used to elucidate the underlying structural organization that initiates these patterns.

1) F. Luangapai and S. Iwamoto, *Int. J. Bio. Macromolecules*, **249**, 126061(2023).

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[1172] Self-assembly mechanism of whey protein hydrolysate and α-, β-, and γ-cyclodextrin nanocomplexes for enhanced bitterness masking and colloidal stability

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This study investigated the bitterness-masking effects and physicochemical characteristics of whey protein hydrolysate (WPH) complexes with α-, β-, and γ-cyclodextrins (CDs). To evaluate the influence of cavity size and binding capacity, WPH was reacted with each CD at molar ratios of 1:0.5, 1:1, 1:1.5, 1:2, and 1:3 (M/M). Free

amino acid analysis indicated that WPH contained a high proportion of hydrophobic residues (Val, Leu, Ile, Phe), accounting for 41.6% of total amino acids, which contributed to its pronounced bitterness. Peptide sequencing (LC–MS/MS, de novo sequencing) confirmed β-lactoglobulin–derived peptides as the dominant components. Gel permeation chromatography showed an increase in molecular weight from 5.8 to 10.9 kDa after complexation, confirming inclusion formation across all CDs. Among the complexes, WPH/α-CD showed limited encapsulation ability due to its smaller cavity (K = 1.71 ± 0.52), resulting in moderate solubility improvement (78–82%) and partial bitterness reduction (~30%). β-CD exhibited the highest inclusion constant (K = 6.58 ± 1.97) and a strong decrease in UV absorption at 288 nm at low to moderate ratios (≤ WPH: β-CD 1:1.5), suggesting efficient encapsulation of aromatic residues ($p < 0.05$). However, at higher ratios (≥ WPH: β-CD 1:2), β-CD complexes showed reduced UV absorbance change and weaker amide I/II band shifts in FT-IR, likely due to aggregation-induced reduction of binding efficiency. This was accompanied by increased turbidity (0.9→1.2 a.u.) and a less negative ζ-potential (−23.7 mV), indicating decreased colloidal stability. In contrast, γ-CD complexes displayed the highest solubility (up to 92%) and the lowest Turbiscan Stability Index, maintaining stable dispersion even at higher CD ratios ($p < 0.05$). TEM images revealed that β-CD induced larger self-assembled aggregates (350–400 nm), whereas γ-CD formed uniform spherical nanoparticles (300–350 nm). Bitterness decreased proportionally with increasing CD ratios, reaching the greatest reduction at 1:2 (M/M) for all complexes. Sensory and electronic tongue analyses confirmed that β-CD reduced bitterness intensity by 50%, γ-CD by 43%, and α-CD by 30%, compared with uncomplexed WPH. α-, β-, and γ-CD showed distinct self-assembly behaviors governed by cavity size and binding densityβ-CD achieved the strongest hydrophobic inclusion and greatest bitterness masking at moderate ratios but suffered aggregation at higher concentrations. γ-CD maintained high solubility and stability, while α-CD showed weaker inclusion but consistent performance. These findings demonstrate that the self-assembly and inclusion behavior of cyclodextrin–WPH nanocomplexes are governed by cavity size, where β-CD maximizes encapsulation efficiency while γ-CD ensures structural stability, providing a molecular basis for optimizing bitterness-masking systems in protein-based food formulations.

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[1173] Study on gels formed by interaction of xyloglucan and locust bean gum

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A mixed aqueous solution of xyloglucan (XG) and locust bean gum (LBG) forms a gel when subjected to freeze-thaw cycles. While LBG alone also forms a gel after freeze-thaw treatment, mixing it with XG produces a synergistic effect, suggesting an interaction between XG and LBG. This effect has been applied in maintaining ice cream shape, and elucidating its mechanism is not elucidated yet. This study reports results using tamarind seed gum (TSG) as XG, observing gelation behavior under freeze-thaw cycles, and structurally investigating the mechanism using scanning electron microscopy (SEM) and small-angle X-ray scattering (SAXS).

TSG and LBG samples were obtained from MP Gokyo Food & Chemical Co., Ltd. SAXS measurements were performed at BL-6A of the High Energy Accelerator Research Organization (KEK).

Melting tests of frozen desserts containing XG and LBG mixtures revealed synergistic effects compared to other polysaccharides. Similar synergistic gelation effects were observed in XG and LBG mixed aqueous solutions. SEM examination of freeze-dried gels revealed a mesh-like structure. Increasing the number of freeze-thaw cycles reduced the mesh size. SAXS measurements also showed increased scattering intensity with more freeze-thaw cycles, indicating enhanced cross-linking regions.

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[1176] Tailored amylose coat on waxy corn starch for consumers with slow swallowing initiation

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Objective: Short-soluble amylose chains have been documented to form an amylose coat over waxy corn starch granules inhibiting gelatinisation and retrogradation. However, certain key questions remain unanswered viz., how does the amylose coat modulate, a) viscosity decay, and b) textural mouthfeel of coated waxy corn starch gels when subjected to simulated oral processing? This study explores these key questions under simulated consumer sensory experience with slow swallowing initiation.

Methodology: Waxy corn starch (ca. 99 % amylopectin, Amioca powder TF-04400108) and isoamylase enzyme (≥10^7 units mg^{-1} protein) were purchased from Ingredion Inc., USA and Megazyme, Ireland, respectively. Mucin type II was purchased from Sigma-Aldrich, India. Short-soluble amylose (DP_{av} ~700) was fabricated from waxy corn starch by isoamylase hydrolysis (40 °C, pH 4.0, 24 h) coupled with aqueous fractionation at 25 °C. Waxy corn starch: short-soluble amylose chain was combined in the ratio, 1:50 (parts by weight) (AP25W-3) while uncoated waxy corn starch gel was used as control. Flow curves were obtained at 37 °C, 1 to 100 s^{-1}, fitted to the Ostwald-de Waele model ($\sigma = k\dot{\gamma}^n$) where, σ is the shear stress (Pa), k is the consistency index ($Pa.s^n$), $\dot{\gamma}$ is the shear rate (s^{-1}), and n is the flow index. Changes in viscosity during simulated oral processing were registered using a starch pasting cell, adapted to a controlled stress rheometer (Anton Paar) with a Peltier concentric cylinder system to control the temperature (37 °C) while shearing (10 s^{-1}) at 37 °C for 120 s using a continuous ramp. To model the viscosity breakdown during the simulated oral digestion, viscosity data under oral conditions (constant shear and, with and without SSF+mucin) was fitted into a second order structural equation, $\frac{n_0-n_e}{n-n_e} = kt + 1$**,** where η is the viscosity at a given time, t is time in seconds. Symbols represent initial apparent viscosity (η_0, Pa.s), the equilibrium apparent viscosity (η_e, Pa·s), and the rate of structure breakdown (k).

Results and Conclusion: Amylose-coated waxy corn maintains an initial smoother texture (0.8 Pa.s), as compared to uncoated waxy corn (1.35 Pa.s) for oral processing without salivary α-amylase. Upon oral processing with salivary α-amylase, the amylose-coated gels retain relatively stable viscosity decay at ca. 40% breakdown while there is a rapid viscosity decay for uncoated gels at over 2× times the amylose coated rate ca. 90% breakdown. In practical terms, starchy food made with amylose-coated waxy corn could feel less “rapidly” watery during oral mastication, as studies explicitly link salivary α-amylase action to rapid in-mouth thinning, a critical window for consumers with slow swallowing initiation.
Such a design could potentially shape starchy food formulations and thickeners for slow-eating children, older adults and dysphagia patients usually with slow swallowing initiation. Hypothetically, this will assist health care providers to tweak the residual oral viscosity and achieve tailored formulations with suitable breakdown during the critical window (oral hold time), thereby reducing the risks of choking from thick or rapidly thinning foods.

Keywords. Amylose coat, Waxy corn starch, Oral processing, Viscosity decay, Slow swallowing initiation, Dysphagia

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[1185] Effects of XG/LBG gel concentration on the stability and rheological properties of G/O/G emulsions

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This study investigated the effects of incorporating xanthan gum (XG) and locust bean gum (LBG) into the inner gel phase (G_1) on the physicochemical properties of gel-in-oil-in-gel (G_1/O/G_2) emulsions, while the outer gel phase (G_2) was kept constant at 0.5%. XG and LBG were combined at a 1:1 ratio to form the G_1 gel matrix, and their concentrations were adjusted to 0, 0.3, 0.5, and 1.0%. The resulting emulsions were evaluated by visual appearance, microscopic observation, confocal laser scanning microscopy (CLSM), particle size analysis, ζ-potential, encapsulation efficiency (EE), rheological characterization, and sensory evaluation. The visual appearance of the emulsions remained uniform with no visible phase separation. Microscopic observation revealed that increasing the inner-phase gum concentration led to finer and more uniformly distributed droplets. CLSM analysis showed that the 0.5% and 1.0% formulations maintained highly stable G_1 droplets, exhibiting insignificant coalescence and strong interfacial stabilization. Particle size analysis showed that the 0% XG/LBG sample had a mean droplet size of 8.80 ± 3.90 μm, whereas the 1.0% formulation exhibited a significantly smaller size of 4.90 ± 1.90 μm ($p < 0.05$), with droplet size decreasing as the G_1 concentration increased. ζ-potential values appeared reduced in magnitude, due to the decreased electrophoretic mobility caused by the gelled outer phase (G_2) compared with conventional emulsions. Encapsulation efficiency analysis showed that the 0.5% formulation achieved the highest retention of the internal aqueous phase, exhibiting the greatest encapsulation efficiency among all samples at 98.2% ($p < 0.05$). Rheological evaluation showed shear-thinning behavior, and G′ consistently exceeded G″, confirming gel-like characteristics. Higher gum

levels strengthened the network, with 0.5% exhibiting the most balanced elasticity. Higher gum content enhanced viscoelastic stability, with the 0.5% and 1.0% formulations maintaining the highest G′ and G″ values across the frequency range, indicating the strongest network structure. The rheological increase in viscoelasticity and network strength corresponded with higher perceived thickness in sensory evaluation. Notably, bitterness intensity was reduced in the 0.5% formulation, which, among all samples, provided the best balance between structural integrity and consumer acceptability. Collectively, the results demonstrate that while increasing XG/LBG concentration enhances network strength and droplet stability, the 0.5% XG/LBG formulation provides the most favorable balance between viscoelasticity, interfacial stabilization, emulsification efficiency, and sensory quality. This gel concentration promotes efficient droplet disruption, enhances encapsulation performance, and ensures sustained structural coherence, thereby representing the optimal formulation level for achieving both physicochemical stability and consumer-preferred quality in $G_1/O/G_2$ emulsions.

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[1188] Effect of the gel state on the biological activity of scleroglucan

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Scleroglucan is a β-glucan with a β-1,3-linked main chain and β-1,6-linked side chains. It shares the same chemical structure as schizophyllan, which is well known for its antitumor activity, and scleroglucan is also recognized as a ligand for Dectin-1. The antitumor and immunomodulatory activities of β-glucans mediated by Dectin-1 have been reported to be significantly influenced by factors such as molecular weight, degree of branching, and stereochemical structure. Notably, it has been reported that particulate β-glucans, rather than soluble β-glucans, must be presented as ligands to activate Dectin-1 signaling.

In our laboratory, we confirmed that scleroglucan aqueous solution forms a true gel when left at 4°C for over 20 hours. In this context, a true gel refers to a semi-solid state

containing a large amount of water and exhibiting a distinct fracture surface upon rupture. Achieving this gel state requires partial association between polymers to form a three-dimensional network structure throughout the material. Compared to the gel, the aqueous solution of soluble β-glucan is a liquid state where individual molecules are dispersed in water, while aqueous dispersions of insoluble particulate β-glucan can be regarded as suspensions where particles formed by the aggregation of numerous molecules are dispersed in water. Therefore, the true gel state of scleroglucan is considered to be distinct from both solution state of scleroglucan and the dispersion state of insoluble particulate scleroglucan. This study investigated the effect of the gel state—neither a solution nor an insoluble β-glucan suspension—on the biological activity of scleroglucan.

A 0.6 wt% scleroglucan aqueous solution containing 70% glycerol formed a true gel upon cooling and maintained its gel state even at 40°C. We examined both applying this true gel directly to the culture plate and applying it to the culture plate in a microgel state. Microscopic observation of the microgel revealed rod-shaped gels exhibiting anisotropy. To evaluate the degree of Dectin-1 activation, the amount of TNFα released from macrophage-like cultured cells RAW264 was compared between cases where this microgel was added and cases where scleroglucan and glycerol in solution were added as a control. The amount of TNFα released from cultured cells to which scleroglucan solution was added to the medium was significantly increased compared to when it was not added. At the conference, we will present the effect of true scleroglucan gel on TNFα release compared to scleroglucan solution or suspension.

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[1190] Pickering emulsion stabilized by seaweed cellulose nanofibers

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The escalating global demand for polysaccharides as gelling agents and thickeners, particularly within the food industry, has intensified seaweed cultivation. While a portion of the residual biomass post-polysaccharide extraction is repurposed as animal feed or fertilizer, the majority is discarded as industrial waste. Due to the low lignin content of seaweed compared to woody biomass, it presents a promising feedstock for the efficient recovery of high-purity cellulose. This study investigates the feasibility of utilizing cellulose

nanofibers (CNFs), derived from seaweed residue, as particulate stabilizers for the formulation of oil-in-water (O/W) Pickering emulsions.
The red macroalga *Kappaphycus alvarezii*, cultivated in Indonesia, served as the raw material. Following carrageenan extraction via hot alkaline aqueous treatment, the residual biomass was subjected to drying, mechanical pulverization, oxidative decolorization using hydrogen peroxide, and acid hydrolysis with sulfuric acid. The resulting CNFs were isolated through successive centrifugation and washing steps to achieve neutral pH.
Emulsification was conducted by dispersing CNFs in deionized water, followed by the addition of soybean oil. The mixture underwent high-speed rotor-stator homogenization to form a coarse emulsion, which was subsequently refined using high-pressure homogenization. Optical microscopy and laser diffraction analysis revealed a monomodal droplet size distribution centered around 15 µm, indicating the formation of a relatively uniform emulsion.
Stability assessments over a 7-day period at ambient temperature demonstrated that approximately 90% of oil droplets remained within the 5 - 20 µm range, with minimal coalescence observed. Even after 50 days of static storage, the droplet size distribution remained largely unchanged. This stability could be explained by the formation of Pickering emulsions, wherein CNFs adsorb onto the oil-water interface, thereby inhibiting Ostwald ripening.
In conclusion, the findings substantiate the potential of seaweed-derived CNFs as sustainable, bio-based stabilizers for the preparation of stable O/W emulsions, offering a viable alternative to conventional synthetic emulsifiers in food and related applications.

Acknowledgements: This research was supported by SATREPS, Japan Science and Technology Agency (JST, JPMJSA2307) / Japan International Cooperation Agency (JICA).

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1193 Collagen hydrolysate–based oral films supporting muscle health and mitigating sarcopenic decline

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Muscle health is vital for quality of life in older adults, but those with dysphagia often struggle to consume conventional protein or amino acid supplements. To offer an easier-

to-consume alternative, we developed orally disintegrating films (ODFs) containing collagen hydrolysates (CH) from pollock skin and citrus peel extract. Two variants were prepared with leucine (0.5–1.0%) or β-hydroxy-β-methylbutyrate (HMB, 0.5–2.0%), designated as CH/Leu and CH/HMB. The films displayed uniform structural properties (thickness 0.21–0.27 mm; opacity 0.18–0.27) and rapidly disintegrated in the mouth (CH/Leu: 10–14 s; CH/HMB: 13–18 s). Surface pH values (5.67–6.93) were within physiologically acceptable limits.

Under simulated gastrointestinal conditions, both formulations showed efficient intestinal release, reaching cumulative release rates of 98% (CH/Leu) and 96% (CH/HMB). Release behavior fit well to the Kopcha ($R^2 \geq 0.996$) and Peleg ($R^2 \geq 0.999$) models, indicating a diffusion-dominant mechanism favorable for targeted nutrient delivery.

To further assess the muscle-supporting potential of the developed ingredients, we evaluated the bioactivity of green tangerine–extracted collagen (GEC) in C2C12 myoblasts. In a dexamethasone (DEX)-induced atrophy model, DEX reduced myotube diameter by 36.6%, while leucine or HMB partially restored it. Although GEC alone had minimal effect, co-treatment with GEC (100 μg/mL) and HMB (50 μM) produced a synergistic increase in myotube diameter that surpassed control levels. Immunofluorescence analysis showed that MyHC expression suppressed by DEX was fully restored by the combined treatment.

Western blot analysis supported these findings by showing that DEX downregulated MyHC, mTOR, and p70S6K while increasing MuRF1 and Atrogin-1. HMB partly reversed these changes, whereas GEC alone showed limited activity. In contrast, co-treatment restored anabolic signaling markers and reduced catabolic regulators to control or below-control levels. These results indicate that GEC enhances HMB-mediated protection against muscle atrophy by promoting anabolic pathways and suppressing muscle degradation.

Overall, CH-based ODFs enriched with leucine or HMB demonstrated favorable physicochemical properties, rapid oral disintegration, efficient intestinal release, and synergistic anti-atrophic effects when combined with GEC. These films offer a safe and practical nutritional strategy to support muscle health in older adults with dysphagia. Further studies should address long-term safety, regulatory considerations, and clinical validation, and explore optimized formulations or additional bioactives for personalized muscle health applications.

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[1204] Microalgal Protein–Alginate Cryogels for Enhanced Lyoprotection, Gastrointestinal Stability, and Controlled Release of *Lacticaseibacillus rhamnoses* GG

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Living drug carriers, including probiotics, prebiotics, and engineered microbes, are reshaping the field of therapeutic delivery by providing dynamic, host-responsive platforms with the capacity to address complex gastrointestinal, metabolic, neurological, and immune disorders. Encapsulation has emerged as a powerful approach to improve probiotics stability and performance by providing physical and biochemical barriers against stress factors. Conventional methods, such as spray-drying, extrusion, or emulsification, can improve survival, but often at the expense of reduced cell viability or limited scalability. Unlike bead- or film-forming processes, cryogelation generates interconnected macroporous networks under sub-zero conditions, allowing high cell loading while maintaining metabolic exchange and recovery of viable cells. These features are particularly advantageous for living drug carriers, as they combine effective protection with structural properties that support the long-term persistence and functional activity of encapsulated microbes.
This study investigated the structural, functional, and biological performance of spirulina (SPI), chlorella protein isolate (CPI), and blended SPI:CPI, sodium alginate (NaAlg) cryogels as delivery systems for Lacticaseibacillus rhamnosus GG (LGG). FTIR confirmed characteristic amide and carbohydrate-associated bands, while deconvolution of the amide I region indicated protein aggregation dominated by intermolecular β-sheet structures. Water sorption analysis revealed type III isotherms with high monolayer moisture contents, attributable to the hygroscopic maltodextrin–protein–alginate matrix. Thermogravimetric analysis showed four major mass-loss events corresponding to residual moisture, glycerol decomposition, polysaccharide breakdown, and protein–carbohydrate degradation. Mechanical testing indicated comparable stiffness and hardness across all formulations, suggesting that structural integrity is governed primarily by ice-templated macroporosity. μCT and SEM visualisation confirmed highly porous (76–78%) cryogel networks with protein-dependent differences in pore-wall smoothness, thickness, and collapse behaviour under high humidity. All cryogels disintegrated rapidly upon hydration, consistent with capillary-driven infiltration and erosion. Semi-dynamic gastrointestinal digestion demonstrated distinct colloidal transitions, with SPI forming compact gastric aggregates that improved LGG retention and controlled release in the intestine. Intestinal viability was highest for SPI cryogels, which also preserved adhesive capacity toward intestinal epithelium, indicating maintenance of key surface structures. Weibull modelling of storage data revealed strong effects of water activity and temperature on LGG survival. At aw 0.11 and 20 °C, shelf-lives ranged from 183–320 days, whereas high humidity or elevated temperature drastically accelerated inactivation.

Across conditions, β values >1 indicated convex inactivation curves associated with cumulative cellular damage. Overall, SPI-based cryogels provided the most robust protection during processing, storage, digestion, and epithelial adhesion, highlighting their potential as effective protein-based carriers for controlled probiotic delivery.

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[1205] Viscoelastic characterisation of high protein ice cream: Predicting tactile sensory properties via time–concentration superposition and large amplitude oscillatory shear (LAOS) rheology

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Ice cream is a complex colloidal food matrix composed of different structural elements, i.e., air cells, ice crystals and partially coalesced fat droplets dispersed in a continuous freeze-concentrated aqueous phase. Owing to the ice cream structural complexity, small amplitude oscillatory shear (SAOS) rheology has been successfully applied for the viscoelastic characterisation of ice cream as influenced by the mix composition, freezing process and frozen storage conditions. Large amplitude oscillatory shear (LAOS) rheology is an emerging characterisation method in the domain of food colloids due to its ability to allow “near real measurement” of complex food systems. Hitherto, LAOS has been successfully employed for the assessment of the techno-functional interplay of food ingredients (e.g. proteins, polysaccharides, fats, etc) and understanding the structural complexity of real food matrices such as emulsions, foams and gels. Nonetheless, the interrelationship between LAOS properties and sensory textural aspects involving large deformation without solid-to-molten physical state transitions has not yet been explored. The aim of the present work was to showcase the feasibility of LAOS as an instrumental tool for associating the changes in the structural integrity of ice cream with its major tactile sensory modalities at serving temperature.
Three common tactile sensory properties of ice cream i.e., resistance to scooping (scoopability), creaminess and gumminess were assessed in high protein formulations differing in their protein to fat ratio ($\varphi_{P/F}$ = 0.9 to 4) and protein source (milk protein concentrate (MPC) vs whey protein isolate-sodium caseinate (WPICAS) 1:1 blend). The complex viscosity – angular frequency data obeyed the TCS principle with the calculated shift factors reflecting effectively the compositional profile of ice creams i.e.,

$a_c \propto \varphi_{P/F}^{1.16}$ and $\varphi_{P/F}^{2.23}$, $b_c \propto \varphi_{P/F}^{-1.27}$ and $\varphi_{P/F}^{-1.75}$ for MPC and WPICAS fortified systems. LAOS assessment revealed a clear impact of protein type and $\varphi_{P/F}$ on the shearing deformation of ice creams. MPC fortification and decrease in the $\varphi_{P/F}$ enhanced the shear flowing ability of the ice creams. In all cases, the onset of shear stiffening and thickening behaviour was observed at shear stresses below the flow point, which indicates gel-like or colloid glass-like structures. According to partial least squares regression analysis, the TCS parameters (a_c and b_c), damping factor (tanδ) and the shear strain (γ_f) and elastic modulus (log G'_f) at flow point were determined as the most important parameters predicting tactile sensory modalities on large deformation (spooning) such as scoopability, creaminess and gumminess.

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1206 ENTANGLE project: Machine learning aided development of industrial galactomannan derivatives from forage legume seeds. A case study on a locust bean gum analogue

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Galactomannans are plant seed-derived polysaccharides widely recognised for their industrial applications. This stems from their inherent techno-functional properties including thickening, gelling, cryogel formation and interface stabilisation. Previous studies have demonstrated that the molecular conformational properties of galactomannans are inextricably associated with their bestowed techno-functionality, with the mannose-to-galactose ratio (M/G) being the most critical parameter. Generally, high galactose substituted galactomannans (M/G ~ 1-2) are well known for their high thickening capacity and cold-water solubility and swelling ability. On the other hand, further increase in the M/G ratio favours the gelling and cryogel forming capacity of galactomannans but compromises their cold-water solvation affinity.
Despite their industrial importance, galactomannans currently face a significant supply-demand gap. This is not only due to the steadily increasing use of galactomannans in industrial commodity applications (food, nutraceuticals, pharmaceuticals, composite materials, etc.) but also to the fact that the yield of galactomannan-producing crops (i.e., fenugreek, guar, tara, carob, and cassia) is being reduced due to climate change and the geographically and ecologically restricted cultivation of these crops. Recently, our team demonstrated that the seeds of forage legume crops such as alfalfa (*Medicago sativa L.)* and clover (*Trifolium pratense L.*) are promising highly sustainable and ecologically

resilient bioresources of industrially relevant galactomannans with an M_w of 1500-2200 kDa and M/G <1.2.
ENTANGLE project aims a machine learning assisted bioprocessing approach for developing galactomannan derivatives of broad techno-functionality including thickening, gelling, texturizing, cryo-structuring and health promoting properties. The present work showcases a bioprocessing-based approach for producing a locust bean gum analogue from alfalfa seeds isolated galactomannans. Compared to the native alfalfa gum (AAG) the modified AAG (mAAG) exerted notably diverse structure conformational properties leading to significantly enhanced thickening and cold-gelling behaviour. mAAG exhibited a mirroring cold-gelling behaviour to purified commercial LBG whilst it outperformed LBG in terms of its cold-gelling and cryogelling synergism with other industrial hydrocolloids such as xanthan gum and kappa-carrageenan.

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[1207] Structure-activity relationship of lichen polysaccharides in immunomodulation and keratinocyte migration

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Bioactive polysaccharides are attractive targets for skin repair and immune modulation, yet lichen-derived polysaccharides remain underexplored. Water-soluble polysaccharides (WSPs) were isolated from *Peltigera praetextata* (PP) and *P. aphthosa* (PA) using the hot-water extraction method and were evaluated for their bioactivities in human health. Composition analysis (HPLC-SEC, FT-IR, and 1D/2D NMR) confirmed that the PP fractions were mannan-rich with a galactomannan-like profile, whereas the PA fractions were enriched in galactose with minor fucose content. PP polysaccharides exhibited significant pro-migratory activity in HaCaT keratinocytes compared with untreated controls. The NaCl-assisted hot-extracted fraction (**2B**) of PP showed dominant activity across assays, accelerating the scratch gap closure and elevating macrophage uptake with minimal cytotoxicity through an autophagy-dependent pathway. Autophagy behaviour

was selectively modulated in RAW264.7 cells but largely unchanged in PC3 cells. Under basal conditions (non-LPS), nitric oxide levels were close to those of untreated controls for most samples. Cytotoxicity was modest overall, with selective cytotoxicity observed in PC3 cells compared with HaCaT keratinocytes. In contrast, galactose-predominant fractions were associated with lower basal nitric oxide output. These findings reveal a structure-activity relationship in which mannose-enriched fractions were associated with pro-migratory keratinocyte responses and enhanced macrophage function, while galactose-rich fractions attenuate inflammatory reactions. This work presents lichen-associated polysaccharides as potential candidates for applications in skin repair and immune modulation.

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[1211] Long-term stability of algal polysaccharides

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Algal polysaccharides are versatile hydrocolloids widely used in both food and non-food applications. Their functional properties, particularly viscosity and gel formation, depend strongly on their molecular weight. While it is well known that isolation and processing can decrease molecular weight and thereby alter viscoelastic behavior, much less is understood about the long-term stability of these polysaccharides during storage as dry powders. Such information is essential for establishing best storage practices and for assessing the reliability of samples used many years after preparation.

In this study, 24 polysaccharide samples were stored as dry powders for 5 and 10 years at room temperature, +4 °C, -20 °C, and -80 °C. Molecular weights were measured by high-performance size-exclusion chromatography, and samples included common algal polysaccharides, such as agarans, carrageenans, and alginates, as well as pullulan, dextran, and pectin for comparison. Comprehensive characterization was performed by NMR spectroscopy, while mineral part composition and sulfate content were quantified by ion chromatography.

Our results show that long-term storage can substantially reduce the molecular weight of polysaccharides, particularly in samples containing low levels of stabilizing metal ions. In some cases, molecular weight decreased by more than 50% over 10 years. Storage at -20 °C significantly limited degradation, whereas samples stored at -80 °C exhibited no measurable decrease in molecular weight even after a decade. For commercial agaroses, the extent of degradation correlated strongly with sulfate content.

These findings highlight the critical importance of low-temperature storage for preserving the molecular integrity of polysaccharides and ensuring long-term sample stability. This

insight is especially valuable for manufacturers and research laboratories, for whom the long-term functional reliability of polysaccharide-based materials is essential.

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[1212] Valorisation of *Podophyllum hexandrum* rhizomes: bioactive polysaccharides from an underutilized biomass

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The roots and rhizome of the medicinal plant *Podophyllum hexandrum* (Himalayan mayapple) are the primary source of podophyllotoxin, a critical reagent for the production of essential anti-cancer medications, etoposide and teniposide. The slow growth and overharvesting of *P. hexandrum* for podophyllotoxins have led to its global endangerment *[1].* After processing for lignans, the remaining biomass still contains undefined and potentially valuable water-soluble compounds.

Anti-inflammatory, antioxidant, and radioprotective properties have been demonstrated in aqueous extracts of *P. hexandrum [2–4]*. Recently, antioxidant and immune-stimulatory properties were attributed to polysaccharides in the fruit of *P. hexandrum* [5], but the polysaccharides present in the rhizome and roots have not been studied. We aimed to valorise this waste product by isolating these polysaccharides, characterising their chemical structure, and evaluating their bioactive properties.

P. hexandrum polysaccharides were extracted under acidic, neutral, and basic pH and at room and elevated temperature conditions, then purified. The molecular weight distributions of isolated polysaccharides were estimated using HPLC-SEC-RI. The structural features were analysed using Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy, and ^{1}H-NMR. Cell assays were used to test for the bioactive properties of the polysaccharides and potential human health benefits were assessed.

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[1213] Sulfation of pectic acids: selectivity and sulfation patterns

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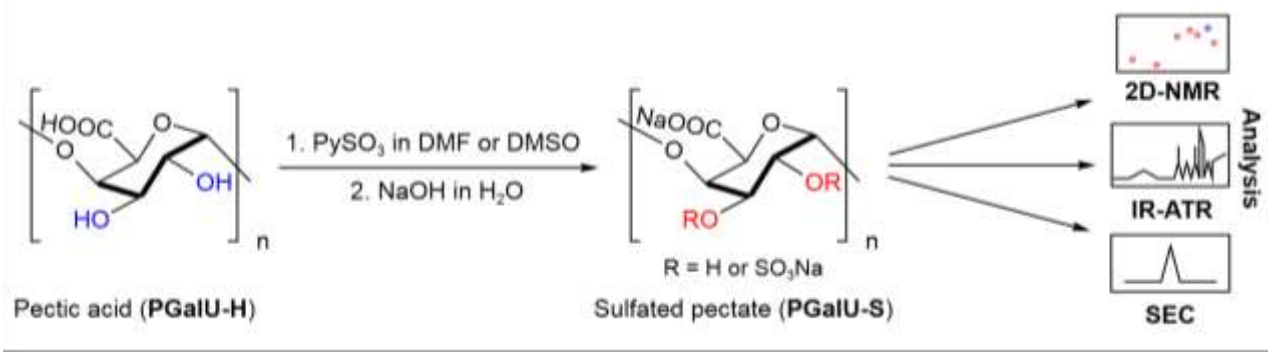
Pectic acids, also known as polygalacturonic acids, are demethylated derivatives of pectins. Sulfated pectins have been found to have anticoagulant[1] and antiviral[2] activity. However, little information exists on sulfation patterns of obtained derivatives, necessitating further study.

In this work, aim was to sulfate and comprehensively characterize the sulfated pectates. To do this, we first sulfated pectic acids in DMF or DMSO with Py·SO_3 in various conditions. Protecting groups, such as benzoyl and TBDMS-group were also used in an effort to obtain regioselectively sulfated pectates, thus further aiding structural characterization. Then pectate sulfates were analysed, primarily with NMR-spectroscopy, but also with IR-spectroscopy, size-exclusion chromatography (SEC) and elemental analysis (EA).

As a result, information on sulfation patterns, including preferential localization of sulfate groups in galacturonic acid residue, was gathered. Such information can be used to rapidly determine sulfation pattern in future works and thus enable easier determination of structure-property relationship for biomedical applications.



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[1214] Food texture evaluation using deep learning and a six-axis sensor equipped tooth-shaped plunger

-Exploring key factors for detailed characterization of food texture-

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About 60% of palatability comes from texture. Sensory evaluation is widely used but depends on subjective factors, while instrumental analysis is objective often disagrees with sensory results. Humans perceive texture through multi-point / multi-directional sensing and texture-dependent mastication, whereas conventional food texture analyzer records only one-axis force during vertical uniform compression independent of each texture. This large gap of experimental conditions is considered a major cause of the discrepancy. Increasing the amount of information obtained during compression and evaluating thousands of measurements could enable more detailed food texture evaluation.

In this study, a machine-learning–based approach was employed to improve the accuracy of texture evaluation to identify key factors contributing to the texture. Two types of automated compression systems were developed. A tooth-shaped plunger and a six-axis force/torque sensor were installed, and compared with the results obtained with conventional simple texture analyzer. Machine learning was applied to the obtained compression results, which is required for more complex results compared with conventional compression instruments. A larger lateral force component was observed with the tooth-shaped plunger than with the conventional disc-shaped plunger. This is likely due to increased lateral sliding during compression of the uneven rice-cracker surface, resulting in larger F_x and M_y values with the tooth-shaped plunger. More than 4,000 compression tests were performed, and two different rice crackers having similar textures were measured. Widely used analysis methods such as TPA (with PCA) could not distinguish the two crackers, whereas the machine learning based method showed higher classification accuracy. Among the six axes, the lateral force component (F_x) and

the rotational moment (M_y) showed improved classification accuracy as the number of measurements increased. These axes reflect lateral movements of the tooth-shaped plunger, suggesting that grinding-type motion plays an important role in texture perception.

The machine-learning–based texture evaluation using a tooth-shaped plunger with a six-axis sensor outperformed conventional methods. The six-axis analysis indicates that grinding-type movements are key factors in detailed texture evaluation.

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1215 3D measurements of chewing behavior toward objective evaluation of human sensory test - application of built-in 3D scanner in smartphone -

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Sensory evaluation is essential in food development, and has been widely used to assess the palatability of food. However, simultaneous evaluation of multiple senses (taste, aroma, and texture) and their interactions make it difficult. This method relies heavily on the subject's verbal expression ability, making it difficult to apply to infants. Furthermore, subjective influences limit reproducibility and objectivity.

It is suggested that biological responses could be an effective method to overcome these challenges. It is known that characteristic facial changes occur in response to taste stimuli such as sourness, and that changes in saliva secretion resulting in taste and/or aroma affected food bolus formation. Differences in food bolus formation are also thought to reflect oral movements, i.e., chewing movements, reflecting each food texture.

We developed a smartphone application to measure temporal changes in facial surface shape during mastication. This application uses a smartphone-mounted 3D scanner to capture a 3D coordinate of the face along three axes over time. Using this method, changes in facial surface shape over time were recorded during chewing of food alone and chewing of food containing added sugar, salt, and vanilla flavoring, several hundred times. Deep learning was employed for texture analysis. Deep learning enables automatic extraction of characteristic values even from huge and complex dataset.

The results showed that the presence or absence of flavor could be determined only from chewing behavior with approx.. 70% accuracy for sweetness and 80% accuracy for saltiness and aroma, demonstrating that chewing behavior changes depending on the flavor. Furthermore, when estimating the flavor concentration perceived by subjects while chewing, it was possible to estimate the concentration for taste/flavor from chewing movements alone.

This study revealed that chewing movements change when flavors are added, and that this reflects the flavor intensity perceived by people.

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[1216] Texture control of laser-based food 3D-printed meat analogues by combining muscle fiber-mimetic structures with material control

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Meat analogues have attracted attention due to protein shortages. One of the major challenges in meat analogue development is the reproduction of realistic food texture. Current meat analogues are limited to soft textures similar to hamburger steak and fail to reproduce the characteristic “chewiness” of steak meat. This unique texture is considered to originate from micro to milli-meter-scale muscle fiber structures and the bonding strength between fibers.

In this study, we developed a laser food 3D printer with the potential to mimic muscle fiber structures. Egg white protein combined with a food-grade yellow dye exhibiting an absorption peak at the laser wavelength was used as the printing material. By uniaxial scanning the laser irradiation path, fiber-mimetic meat analogues were produced, and their mechanical properties were evaluated by uniaxial compression tests. This method enabled not only the creation of fiber-like structures but also the control of inter-fiber bonding strength by adjusting laser irradiation positions. By varying the inter-fiber distance, a wide range of textures was achieved, reproducing mechanical properties ranging from easily separable, braised-meat-like textures to steak-like chewiness based on maximum compressive force during fracture tests.

However, sensory evaluation revealed excessively high cuttability and insufficient rubber-like elasticity (springiness). Since texture depends on by both structural design and material properties, material-based modifications were further investigated. Methylcellulose (MC) was incorporated to control texture through changes in crosslinking structures. After laser fabrication followed by cooling and reheating, the printed meat analogue made from MC-containing egg white food ink exhibited more than twice the maximum compressive force compared to that made from egg white alone, along with more gradual post-fracture behavior. Rheological measurements showed an increase in storage modulus (G′) during reheating, indicating reversible reorganization of MC networks.

These results demonstrate that realistic food texture control of meat analogues can be achieved through the combined design of structure and material properties.

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[1217] Physicochemical and Techno-Functional Characterization of Protein Extract from Fermented Soybean by Product (Okara) and Its Application in Mayonnaise

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Tempeh gembus is a traditional Indonesian fermented food, but it typically has a short shelf life and low economic value. These limitations can be addressed by processing it into flour or hydrolysates, followed by protein extraction to improve its physicochemical and techno-functional properties. Tempeh protein possesses excellent techno-functional traits such as water holding capacity (WHC), oil holding capacity (OHC), and emulsion stability. This study explores the application of protein extract from tempeh gembus flour as an emulsifier in mayonnaise, a semi solid oil in water (O/W) emulsion that relies on emulsifiers for stability. The research aims to evaluate the functional properties of the protein extract, including its suitability as a plant based emulsifier in mayonnaise formulations. The physicochemical (color, protein, fat, moisture, ash, carbohydrates, amino acid composition) and functional (WHC, OHC, emulsifying activity and stability) characteristics of the protein extract were analyzed. Additionally, mayonnaise formulated with varying concentrations of the protein extract was assessed for physicochemical properties, rheological behavior, emulsion stability, and sensory acceptance. Results showed that the protein extract had a lighter color and higher protein, ash, fat, and amino acid content than the flour. It also exhibited superior WHC, OHC, and emulsifying properties. Increasing extract concentration in mayonnaise increased protein and ash content while decreasing fat content, with no significant difference in overall consumer preference compared to the control. This suggests that tempeh gembus protein extract is a promising functional ingredient for more nutritious and stable mayonnaise products.

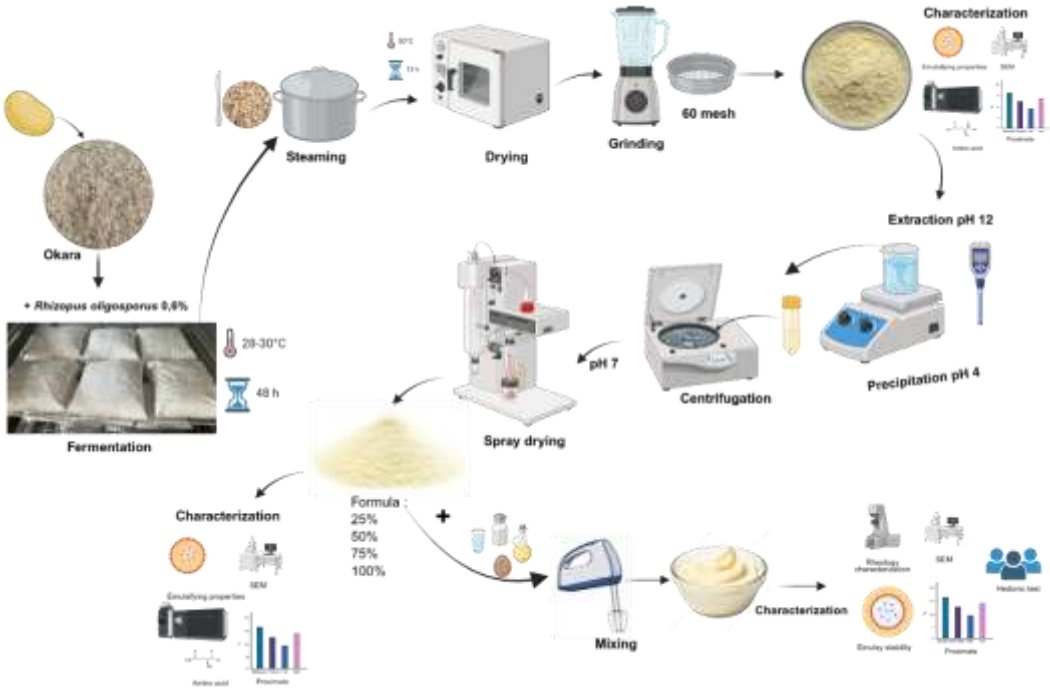

Figure 1. Graphical Abstract

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[1218] Mycelium-based high-fiber bread: the role of *in-situ* produced structurally different dextrans on the texture and digestion properties

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Fungal mycelium is rapidly emerging as a next-generation food ingredient due to its high fiber and protein content, efficient upcycling of agro-industrial waste, and low environmental impact. In this study, we investigated for the first time the role of *in-situ* produced dextran in modulating the texture and digestibility of high-fiber bread formulated from a 50:50 blend of *Cordyceps sinensis* mycelium and wheat flour. We compared two structurally distinct dextrans, high molecular weight and linear structure from *Weissella confusa* VIII40, and lower molecular weight and highly branched structure from *Pediococcus beninensis* DSM 22752. Our findings demonstrate that fermentation with *W. confusa* VIII40 yielded 4.9% (dw) dextran, which significantly improved loaf specific volume, reduced crumb hardness, and delayed staling compared to control, effects not observed with dextran (2.22% dw) from *P. beninensis* DSM 22752 . *In-situ* produced dextran from *W. confusa* VIII40 significantly enhanced the bread's nutritional profile, increasing DPPH radical scavenging activity and bile acid binding activity, while lowering the starch hydrolysis index (HI) and estimated glycemic index (eGI). These effects were linked to partial fiber solubilization and increases in digesta viscosity (2.6-fold) and particle size (1.6-fold) during intestinal digestion.

Overall, integrating *C. sinensis* mycelium with *in-situ* dextran production via fermentation presents a promising strategy for developing clean-label, high-fiber functional breads with improved texture and health-promoting properties.

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1221 Physical property development in starch gelatinization probed by Rheo-SALS and Rheo-Impedance

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Objective
The physical properties of food hydrocolloids are critical for determining texture and quality in food products. In starch-based systems, gelatinization governs the emergence of mechanical rigidity during heating; however, the relationship between microscopic structural changes and macroscopic physical properties remains unclear. In particular, it is still debated which events directly control the onset of rapid mechanical property development relevant to formulation and processing. This study aims to clarify the mechanism of starch gelatinization by identifying how morphological and electrochemical changes precede and converge to trigger macroscopic mechanical transitions, using simultaneous real-time measurements under identical thermal conditions.

Methods
A 10 wt% aqueous wheat starch paste was heated under controlled conditions while its physical properties were monitored using simultaneous rheological, optical, and electrochemical measurements. Rheology was used to track the evolution of elastic moduli (G', G"), morphological changes of starch granules were observed by Rheo-small angle light scattering (Rheo-SALS), and electrical impedance was measured by Rheo-Impedance. The impedance spectra were analyzed using a simplified Hayden model to evaluate changes in the continuous phase and granule interiors associated with amylose dissolution.

Results
G' and G" of the starch paste remained low at lower temperatures and sharply increased at approximately 65 °C, indicating the onset of macroscopic gelation. In contrast, microscopic and electrochemical changes occurred at lower temperatures. Rheo-SALS measurements showed that the characteristic Maltese cross scattering pattern, originating from the concentric layered crystalline structure of starch granules, weakened between 55

and 60 °C, accompanied by rapid granule swelling. Rheo-Impedance analysis revealed significant decreases in both the resistance of the continuous phase R_1 and the internal resistance R_2 of starch granules in the same temperature range, reflecting the release of amylose and electrolytes into the continuous phase.
Importantly, these morphological changes and the onset of amylose dissolution did not result in an immediate increase in elastic moduli. The macroscopic gelation temperature was clearly higher than the temperature at which granule swelling and amylose release began. The sharp rise in elastic moduli was observed only when the morphological and electrochemical changes converged, demonstrating that initial amylose release is insufficient to induce gelation. These results indicate that the temperature associated with morphological changes and amylose dissolution is distinct from that of macroscopic gelation.

Conclusion

Starch gelatinization does not occur instantaneously upon granule morphological changes or amylose release into the continuous phase. Instead, macroscopic gelation emerges only after the concentration of dissolved amylose exceeds a critical threshold required for a percolation transition. Thus, morphological transformation and amylose release are necessary but not sufficient conditions for gel formation. This clear separation between microscopic transformation temperature and macroscopic gelation temperature provides a mechanistic framework for understanding physical property development in starch-based food systems and offers practical guidance for controlling texture through formulation and thermal processing.

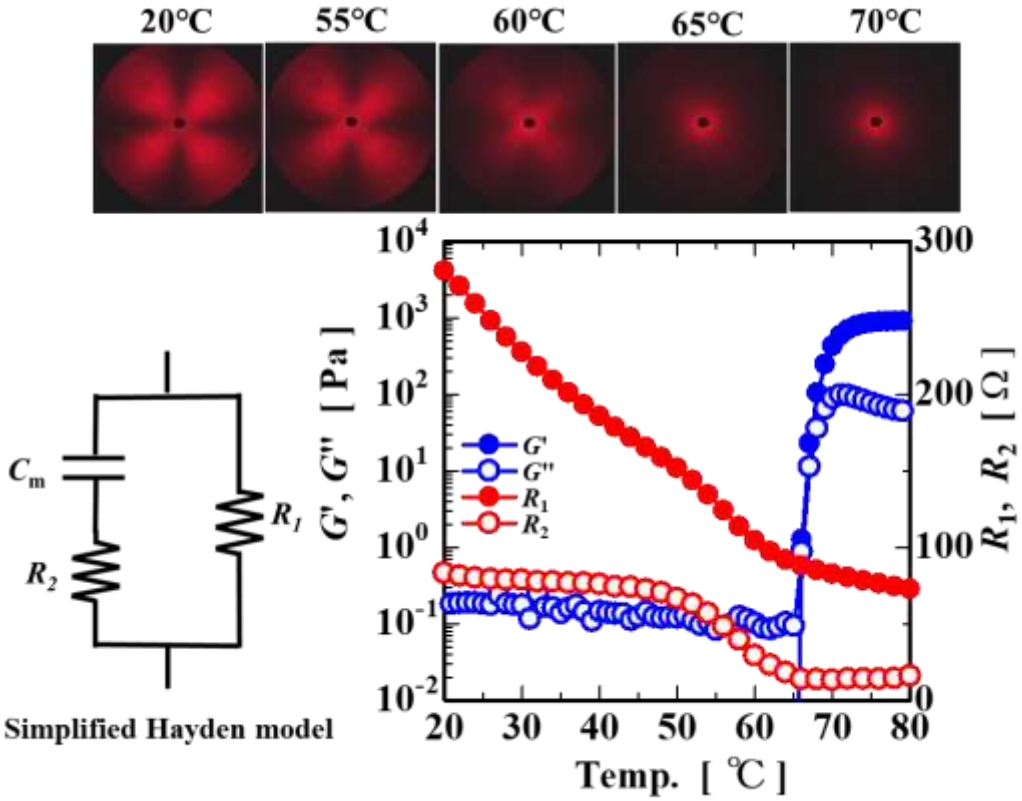

Figure 1. Hayden model representation of a starch paste and simultaneous changes in rheological properties, SALS patterns, and electrochemical characteristics during the gelatinization process.

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1222 Effects of Water-Addition Level and Pre-Gelatinized Starch (Rice Porridge) on the Retrogradation and Nanoscale Structural Development of Rice Gels

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Starch-based foods often undergo quality deterioration during low-temperature storage due to starch retrogradation, and the incorporation of pre-gelatinized starch has been proposed as a strategy to mitigate this problem[1)]. Rice porridge can be regarded as a form of pre-gelatinized starch, and previous studies have shown that its addition accelerates

recrystallization under low water-addition levels but suppresses it under high water-addition levels. These contrasting effects suggest that the hydration environment plays a decisive role in determining how pre-gelatinized starch influences retrogradation, yet the underlying structural mechanisms remain unclear.
This study aimed to clarify how different water-addition levels affect the gelatinization and retrogradation behavior of rice flour gels, and to elucidate how the composition of the pre-gelatinized starch contributes to nanoscale structural changes during heating and storage. Rice flour gels were prepared by mixing rice flour with 1–2× water and replacing 0–20% of the flour with porridge made from non-glutinous rice. The suspensions were gelatinized at 100 °C for 30 min, stored at 15 °C for up to 4 days, and analyzed by X-ray diffraction to determine recrystallization. Time-resolved SAXS measurements were conducted during heating from 30 to 95 °C to evaluate changes in lamellar structure, and scattering profiles were analyzed to obtain the long period and the thicknesses of amorphous and crystalline layers.
Recrystallization increased with the addition of porridge under 1–1.25× water but was suppressed under 1.75–2× water, with 1.5× water showing transitional behavior depending on the amount added. SAXS analysis revealed that porridge had little influence on nanoscale structure during gelatinization at 1× water, whereas at 2× water it increased the lamellar long period by altering the balance between amorphous and crystalline layer thicknesses. These findings demonstrate that the effect of pre-gelatinized starch on starch retrogradation and nanoscale structural development is governed primarily by the water-addition level, and that pre-gelatinized starch can either promote or suppress retrogradation depending on the hydration conditions during preparation.

1) Y. Dang et al, *Food Hydrocolloids*, 109159, (2023).

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1223 Reversible and irreversible changes in protein secondary structure in the heat- and shear-induced texturization of native pea protein isolate

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The molecular mechanism of plant protein texturization under extrusion conditions was unraveled at the secondary structure level by decoupling the effects of heating, cooling and shearing on protein secondary structure. Native pea protein isolate hydrated at 50 % w/w in H_2O and in D_2O, to allow detailed resolution of protein secondary structure, was subjected to temperature cycling in a temperature-controlled ATR-FTIR and was

texturized at the gram scale by microcompounding. Upon heating without shearing, native α-helices and intramolecular-β-sheets unfold to random domains, followed by the formation of intermolecular β-sheets, inducing aggregation. During cooling, the intermolecular β-sheets become increasingly ordered, and random domains partially fold into non-native β-structures. Combined heating and shearing results in more extensive β-sheets than heating alone. The resulting β-rich structures provide for an entangled network of protein chains and a cohesive protein matrix. The effect of shear on protein association/dissociation is controlled by the specific mechanical energy (SME), with the degree of intermolecular β-sheet formation increasing with increasing SME values up to ~1000 kJ/kg, followed by a gradual decrease with further increases of the SME. The detailed molecular insights in the mechanism of plant protein texturization allows for a more controlled design of novel food products, including matrices for use in meat analogues.

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1224 Exogenous α-glucosidase enzyme alters the histological structure and retrogradation inhibition of cooked rice grains

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Endogenous and added enzymes influence the sensory properties of cooked rice by acting on starch during gelatinization. This study elucidated the distinct spatial distributions and structural effects of endogenous α-glucosidase (E-AG) and exogenous α-glucosidase derived from *Aspergillus niger* (A-AG) during cooking. As shown in Fig.

1(a), E-AG was distributed throughout the raw grain after soaking for 1 h in an aqueous A-AG solution, whereas A-AG penetrated the grain and localized along the cell walls. With A-AG, the cooking time was prolonged by approximately 1 min, and the temperature rise from 85 to 100 °C became more gradual. This phenomenon is attributed to increased endothermic reactions caused by the enhanced starch hydrolysis and gelatinization that occur in enzyme-added rice. A-AG acts not only on the surface layer but also on the inside of the rice grains and contributes to the suppression of starch retrogradation, as shown in Fig. 1(b). Our research indicates that A-AG's preservation effect is related to its localization.

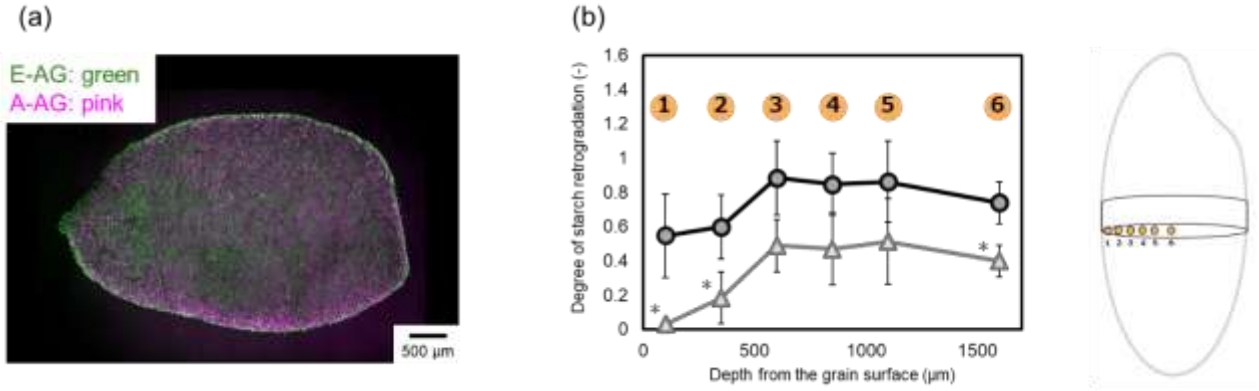

Fig. 1 (a) Double fluorescent immunostaining images of rice grains soaked for 1 h in an A-AG solution. E-AG: green, A-AG: pink (penetrating the grain). (b) Intragranular distribution of the starch retrogradation degree in cooked rice grains, measured by X-rays at 6 sites after being stored for 2 days at 15 °C. Control (○) and A-AG-treated (Δ) samples. Retrogradation was suppressed at all measurement sites by A-AG addition (n=3, *p<0.05).

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[1018] Effects of xyloglucan on metabolism in humans (preliminary study)

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【Objective】 After Fukushima disaster in 2011, radioiodine fallout could be largely incorporated and fixed in the xyloglucan of cell walls in Fukushima forest trees. Since xyloglucan has been used for the food glycan, we attempted to use xyloglucan instead of

the stable iodine tablets for human bodies against radioiodine. At first, we examined the levels of non-digested xyloglucan through human bodies and also the effects of xyloglucan on the bodies.

【Method】 Three healthy subjects were given 10g x 7days of xyloglucan, and their excretion in the stool was examined. Ten healthy subjects their 20s who were subjected to a normal initial triglyceride level range of 60-150 mg/dl were selected and subjected to 10 g of xyloglucan per day for 7 days to examine changes in blood parameters between before and after intake of xyloglucan was determined by t-test.

【Result】 In three healthy subjects of xyloglucan was metabolized and remained 4.1% in the stool. The change in mean stool volume due to xyloglucan ingestion increased from 128 g/day before ingestion to 161 g/day after ingestion period.

In ten healthy subjects xyloglucan ingestion significantly reduced significantly ($p<0.05$) both blood cholesterol levels from 175.4 mg/dl to 166.7 mg/dl and triglycerides from 98.8 mg/dl to 73.4 mg/dl, respectively.

This is the first report on the effect of improving lipid metabolism in continuous intake of xyloglucan in humans. In this study, the presence of xyloglucan in feces was small, suggesting the effect of assimilation by intestinal bacteria and the effect of short chain fatty acids, which are assimilation products, on lipid metabolism.

1)Nonaka, M. et.al Forests, 11, 957,1-10(2020); doi:10.3390/f11090957

www.mdpi.com/journal/forests

2)Yamatoya, K. et. al, In Hydrocolloids Part 2,p.405-410.(2000)

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[1020] Effects of Spray-Drying Carrier on Physical Properties of Mucilage Powder Extracted from Lemon Basil Seed Using Ultrasonic-Assisted Extraction

Ruengwit Sawangkeaw[1*, **], Wirasinee Supang[1], Chatchaphong Nakphadungsuk[1], Nattapach Rithruthai[2], Napasorn Champare[2], Arthitthaya Chawchai[2], Winatta Sakdasri[2], Natthaporn Chotigavin[2]

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The mucilage from lemon basil (*Ocimum* × *africanum* Lour) seeds serves as an excellent food hydrocolloid and can be extracted using ultrasonic-assisted extraction (UAE). Previously, the seeds were soaked in deionized water at a solid-to-liquid ratio of 1:40 (w/w) before applying UAE. The extract contained only 0.6 g of solid per 100 g of solution. Despite its high viscosity of 70 mPa·s, the mucilage was successfully turned into a powder, with a moisture content below 2% (w/w) through spray drying. Maltodextrin at

15% (w/w) was added as a carrier during spray drying to improve solid recovery. However, the initial results showed no significant improvement in solid recovery; the physical properties of the extract needed clarification. In the preliminary study, the SEM micrographs revealed that the addition of maltodextrin altered the shape and increased the particle size of the powder.
To estimate the effect of maltodextrin, other physical properties, such as water and oil absorption capacity, emulsification stability, and dispersion stability, of the spray-dried powder were also measured. Furthermore, the rheology of the extracted and rehydrated mucilage was examined in this work.

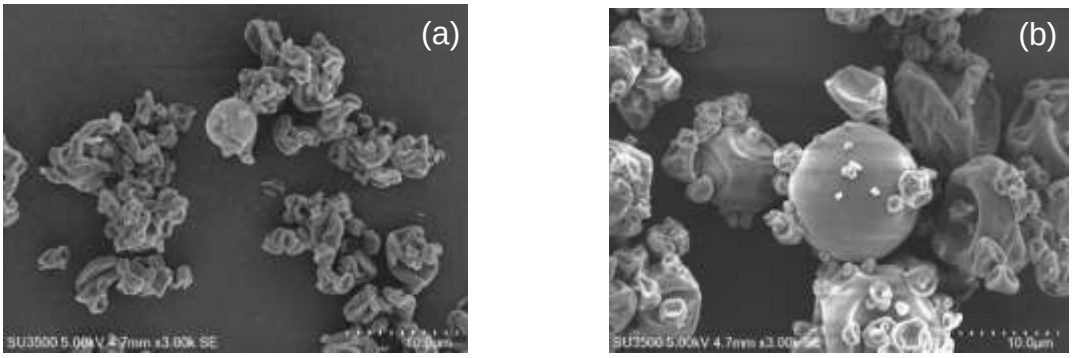

Fig 1. SEM micrographs of (a) mucilage powder spray dried without maltodextrin and (b) mucilage powder spray dried with maltodextrin

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1043 Fermented Pea Protein as a Functional Ingredient in Plant-Based Drink

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Abstract
Dairy-free milk alternatives have become one of the most dynamic segments in the plant-based beverage sector and is largely driven by shifting consumer dietary habits, including a greater emphasis on plant-forward diets. Pea protein due to its favorable amino acid composition, high digestibility, and comparatively low environmental footprint was the plant-based protein studied. However, its poor solubility adversely affects not only protein functionality but also the texture, stability, and overall sensory quality of finished products. A further barrier to consumer acceptance is the presence of characteristic “beany” or “grassy” off-notes, which can dominate flavor profiles and limit market success.
Fermentation techniques were used to address these functional and sensory limitations. More specifically, Shiitake mushroom (*Lentinus edodes*) mycelium fermentation with pea protein was studied to delivered both nutritional benefits and unique flavor compounds.
This study investigates the impact of shiitake mushroom mycelium fermentation on the physicochemical, functional, nutritional, and sensory characteristics of pea protein. Key parameters examined include changes in protein and ash content, protein solubility, and water- and oil-holding capacities. *In vitro* protein digestibility of non -fermented and fermented pea protein was measured using two methods-the pH drop method and a 2step procedure using pepsin and pancreatin.
Functional properties were evaluated through foaming capacity and foam stability measurements, while amino acid profiling and Size Exclusion Chromatography was performed to assess protein depolymerization and nutritional quality. Sensory analysis focused on the reduction of characteristic off-flavors and improvement in overall flavor acceptability. Chromatograms from the UV detector for control and fermented pea proteins showed no change in protein retention time, indicating fermentation did not depolymerize proteins
The fermented proteins were then incorporated into model plant-based beverage systems to evaluate microstructural stability using microscopy and light scattering techniques, and their composition and sensory performance were benchmarked against commercial plant-based protein beverages. Non-fermented and fermented pea protein, the drinks made from each and the commercially available pea protein drinks were analysed for the flavour compounds guanosine-5' monophosphate (GMP), uridine-5' monophosphate (UMP), inosine-5' monophosphate (IMP), adenosine -5' monophosphate (AMP), monosodium glutamate (MSG)
Collectively, these findings provide insights into the potential of shiitake fermentation as a strategy to enhance the technological functionality, sensory appeal, and market competitiveness of pea protein–based dairy-free beverages.

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[1061] Effects of tamarind seed gum in frozen desserts: ice crystal stabilization and shape retention

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INTRODUCTION

The key effects of polysaccharides in frozen desserts are “ice crystal stabilization” and “shape retention”. In this study, these two effects of tamarind seed gum (TSG), a polysaccharide first industrialized in Japan, were investigated by comparing it with locust bean gum (LBG) and guar gum (GG). In particular, the effect of TSG on the stabilization function of ice crystals was quantitatively clarified.

METHODS

Frozen desserts were prepared using standard formulations containing polysaccharides: TSG (0.30 wt%), LBG (0.30 wt%), GG (0.30 wt%), and a combination of TSG (0.15 wt%) + LBG (0.15 wt%). To evaluate the shape retention effect, the weight of melted product was measured after leaving the samples at room temperature.

The morphology of ice crystals was evaluated using the analysis of curvature distribution, following the method proposed by Matsukawa et al. (2024). In this approach, a series of three consecutive points on the ice crystal surface is selected at regular intervals, and the curvature at the central point is calculated based on the radius of a circle passing through the three points. Then, a curvature distribution is plotted using the calculated curvature values.

The samples composed of 60 wt% sucrose and polysaccharide aqueous solutions were frozen and stored at −28°C for either 3 or 14 days prior to evaluation.

RESULTS

The weight of melt loss after leaving frozen desserts containing each polysaccharide at room temperature for 60 minutes was measured in the following increasing order: TSG+LBG < LBG < TSG < GG. The loss weight of TSG+LBG sample was less than 10%, while that of other samples were exceeded 80%. It was confirmed that the combined use of both TSG and LBG dramatically improved the shape retention of frozen desserts.

The ice crystal morphology was also analyzed. The curvature distributions of ice crystals for samples are shown in Fig. 1. For all samples, the curvature distribution changed from 3 days to 14 days of storage: peaks in the high-curvature range (reflecting round shapes) decreased, while peaks in the low-curvature range (reflecting flat shapes) increased. This reflects the visual change in ice crystal images which shows the amount of large and flat-faced ice crystals was increasing over the frozen storage period. After 3 days of storage, differences between the added polysaccharide types were not significant. However, after 14 days of storage, differences among each polysaccharide became apparent. Compared to LBG and GG, TSG exhibited a larger peak in the range of high curvature and a smaller peak in the range of low curvature. It indicated that the addition of TSG restrained the flattening of ice crystals. Furthermore, when TSG and LBG were combined, the

restraining effect was stronger than TSG. This suggests that the addition of TSG, particularly the addition of combined TSG and LBG, suppressed changes in ice crystal shape during the frozen storage period, thereby stabilizing the ice crystals.

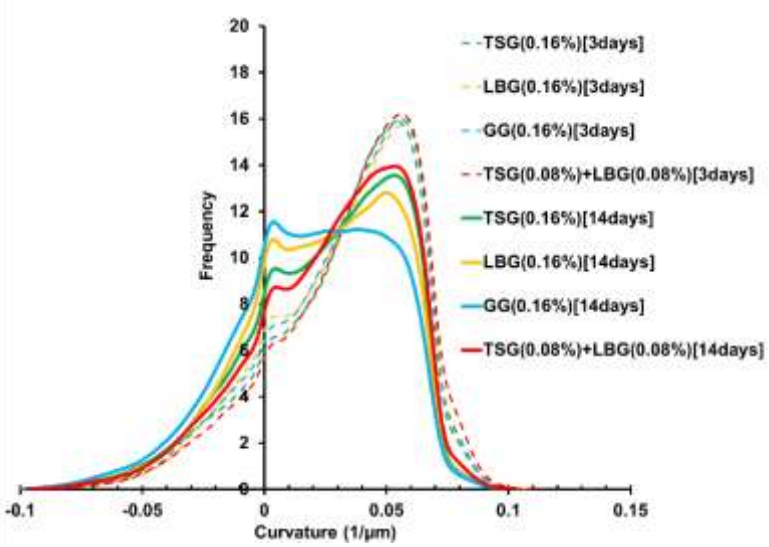

Fig. 1 Curvature distributions of ice crystals in 60% sucrose solution containing different polysaccharides after frozen storage for 3 and 14 days.

Acknowledgements. Authors wish to thank Professor Matsukawa of Tokyo University of Marine Science and Technology for his valuable guidance.

Reference

[1] S. Ahmed, X. Yang, and S. Matsukawa, 'A Novel Method for Analyzing the Ice Crystal Shape from the Curvature of Ice Crystals', Transactions of the Japan Society of Refrigerating and Air Conditioning Engineers, 2024, doi:10.11322/tjsrae.24-21

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1064 Functional potential of protein isolates from narrow-leafed lupin (*Lupinus angustifolius*) versus soy (*Glycine max*) for food innovation

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Soy (*Glycine max*) has long been the most widely used plant-based protein source, widely adopted as an alternative to animal-derived foods. However, as global demand for plant proteins continues to rise, reliance on a single legume crop, such as soy, causes sustainability and supply challenges. Consequently, research attention has shifted towards identifying alternative, underutilised legumes with favourable nutritional and environmental benefits for human consumption. *Lupinus angustifolius* L. (Australian sweet lupin or narrow-leafed lupin) has emerged as a promising crop due to its high protein and dietary fibre content, absence of trypsin inhibitors, and non-GMO status, compared to soybeans. From an environmental viewpoint, lupins are well-adapted to acidic and sandy soils, requiring minimal fertiliser input, and offer a resilient and sustainable option for cultivation in resource-limited agricultural systems. Protein isolates were extracted from dehulled seed flour of five *L. angustifolius* genotypes grown at an experimental site in Merredin, Western Australia, using alkaline extraction and isoelectric precipitation. The resulting isolates were subjected to a comparative evaluation of their thermal, structural, and rheological characteristics, with commercial soy protein isolate (SPI) serving as a reference material. Statistical analysis was conducted using IBM SPSS Statistics (Version 30, 2024). One-way analysis of variance (ANOVA) with Tukey's HSD post hoc test was performed to determine significant differences between groups at $p \leq 0.05$. The DSC thermograms, FTIR spectra, and rheological curves were processed using TRIOS (v5.3, 2023), OPUS (v7.0, 2019) and RheoCompass™ (v1.32, 2023) software, respectively. Fourier Transform Infrared (FTIR) analysis indicated that β-sheets were the most abundant secondary protein structure in lupin protein isolates (LPI), followed by α-helices, with a comparable pattern observed in SPI. Differential Scanning Calorimetry (DSC) revealed two distinct denaturation transitions in the LPI, with peak denaturation temperatures (Td) observed between 84-86°C and 96-98°C, corresponding to the thermal unfolding of the β-conglutin and α-conglutin fractions, respectively. In contrast, the first two thermal transition peaks, corresponding to β-conglycinin and glycinin, respectively, were absent in the soy protein isolate, possibly due to protein denaturation caused by the extraction and post-extraction conditions or the high temperatures employed during spray or drum drying in the commercial production of soy protein isolate. The protein network of LPI lacked a well-defined structure and exhibited a slightly porous, irregular morphology. The microstructure of lupin proteins was less interconnected than soy, which had a more

compact and continuous protein network. Rheological analysis showed that LPI formed weaker and more easily deformable gels, as evidenced by their lower complex viscosity (η*), storage modulus (G′), and loss modulus (G″), along with a higher loss factor (tan δ) relative to SPI. Despite forming comparatively weaker gels than soy proteins, lupin proteins demonstrated higher denaturation temperatures and greater thermal resilience, indicating their potential suitability for incorporation into thermally processed, high-protein food systems. Overall, these findings highlight both the challenges and opportunities of using lupin protein isolates in plant-based products, emphasising the need for targeted process modifications to improve gelation and exploit the thermal resilience of *L. angustifolius* for future food innovations.

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1065 The rheological properties of the concentrated solid-liquid dispersion systems

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When solid food enters the oral cavity, it is masticated, crushed, and mixed with saliva to form a food bolus, which can be regarded as a concentrated solid-liquid dispersion system. In this study, we examined the physical properties of such concentrated solid-liquid dispersion systems and investigated parameters related to masticatory characteristics from the perspective of food science.

Gelatin was selected as the solid-phase material. The solid-phase material was molded into cubes with sides of 10 mm and subjected to compression tests using a creep meter RE2-3305s (Yamaden Co., Ltd.) at a compression speed of 1 mm/s. The Young's modulus, rupture stress, rupture strain, and rupture energy were determined from the resulting stress–strain curves. To prepare the concentrated solid-liquid dispersion samples, the solid-phase materials were crushed using a sieve (6.7 mm mesh, Tokyo Screen Co., Ltd.) and mixed with pure water. The loss modulus (*G″*) of the prepared concentrated solid-liquid dispersion samples was measured at 25 ℃ using a Rheolographsol (, Toyo Seiki Co., Ltd.) under the conditions of ±50 μm amplitude and 3

Hz frequency. In addition, the particle size distribution of the crushed material was measured from micrographs.

The G'' of the concentrated solid-liquid dispersion samples followed a power-law relationship expressed as $G'' = Ks \cdot W^m$. Where Ks is the proportionality coefficient, W is the solid weight fraction, and m is the nonlinearity index. Here, Ks represents an index of bolus fluidity, while m serves an index of salivary disintegration. A value of m greater than 1 indicates a high degree of salivary disintegration. Furthermore, the energy required to increase the surface area of fragmented material was evaluated by dividing the work necessary for fragmentation by the corresponding increase in specific surface area (ΔS). This value was regarded as an index of masticatory disintegrability. Assuming that the work required for fragmentation is proportional to the rupture energy (E), the ratio $E/\Delta S$ was defined as the apparent rupture surface energy. The results suggest that the apparent rupture surface energy and the nonlinearity index m can be effectively used as indicators for classifying and evaluating the masticatory characteristics of foods.

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[1074] Enhancement of the solubility of poorly soluble compounds by low-molecular-weight tamarind seed polysaccharide

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Introduction. Many functional food ingredients, such as polyphenols and fat-soluble vitamins, exhibit poor water solubility, which limits their absorption, stability, and application in easily consumed functional foods such as beverages. Curcumin is a representative example of a poorly soluble bioactive compound. Tamarind seed polysaccharide (TSP), a natural thickening polysaccharide derived from the seeds of *Tamarindus indica* L., is widely used in food and cosmetic formulations. Previous studies have reported that hydrolyzed TSP with a lower molecular weight can enhance the water solubility of curcumin. Building upon this finding, we investigated whether low-molecular-weight TSP (LMW-TSP) could improve the solubility and emulsifying ability of other poorly soluble substances.

Method. LMW-TSP was prepared through a controllable depolymerization process that is easier to regulate than conventional enzymatic hydrolysis. The solubilizing and emulsifying abilities of the resulting LMW-TSP samples were compared with those of native TSP by measuring the absorbance at 440 nm and 300 nm, using curcumin and fat-soluble vitamins as model compounds. Their physicochemical properties were also evaluated by viscosity measurements using a rheometer. Furthermore, their stability was

assessed by measuring the absorbance of dispersions of curcumin or fat-soluble vitamins stored for a certain period at a specific temperature.
Results. We identified a distinct molecular-weight range of LMW-TSP that effectively enhanced the solubility of curcumin, differing from previously reported ranges. Furthermore, LMW-TSP exhibited a unique emulsifying effect on fat-soluble vitamins, particularly vitamin E. These results suggest that LMW-TSP may facilitate nutrient dispersion and absorption, contributing to the development of novel functional food ingredients.

1) Lang W., Tagami T., Kang H.J., Okuyama M., Sakairi N., Kimura A. (2023). Partial depolymerization of tamarind seed xyloglucan and its functionality toward enhancing the solubility of curcumin. *Carbohydrate Polymers*, 307, 120629.

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1098 Starch–lipid complexation induced by mayonnaise addition enhances RS5 formation and modulates digestion behavior in cold-stored mashed potatoes

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Abstract
Background & Objective: The modulation of starch digestibility through hydrocolloid interactions has garnered significant attention in the design of functional low-glycemic foods. However, the mechanistic role of common food emulsions, particularly mayonnaise, in promoting resistant starch formation during cold storage remains underexplored. This study aimed to elucidate how mayonnaise-induced starch–lipid complexation influences the crystalline structure, enzymatic digestibility, and glycemic potential of cold-stored mashed potatoes, with a focus on RS5-type resistant starch development.

Methods: A model food system was constructed using mashed potatoes with or without mayonnaise (105g potato:24g mayonnaise), subjected to cold storage at 0°C and 10°C for 0–72 hours to simulate commercial cold-chain conditions. Texture Profile Analysis (TPA) assessed product quality, while structural changes were characterized using X-ray diffraction (XRD), differential scanning calorimetry (DSC), and Fourier-transform infrared

spectroscopy (FTIR). Starch digestibility and estimated glycemic index (eGI) were determined via the standardized INFOGEST 2.0 in vitro digestion model, with correction based on total starch content.

Results: The results revealed that mayonnaise addition significantly preserved textural integrity and promoted the formation of B+V-type crystalline patterns, indicating the presence of amylose–lipid V-complexes (RS5). FTIR spectra confirmed the interaction between amylose and unsaturated fatty acids, while DSC thermograms exhibited distinct phase transitions corresponding to RS5 formation, differentiating it from retrograded RS3. In vitro digestion data demonstrated that mayonnaise-containing samples exhibited a 15–28% reduction in eGI and a marked increase in resistant starch fractions, particularly after 72h at 0°C. Compared to control samples, these structural transformations correlated with lower enzymatic accessibility and improved nutritional properties.

Conclusion & Innovation: This study provides the first comprehensive mechanistic insight into how mayonnaise—beyond its deliciousness—can actively induce RS5 formation through starch–lipid complexation during cold storage. The findings establish a novel application of food-grade emulsions in modulating the digestion behavior of starch biopolymers and support a practical strategy for low-GI food formulation. The implications extend to both scientific understanding and commercial development of functional starchy foods with improved glycemic performance.

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[1106] Preparation and Evaluation of a Polyphenol-Containing Tamarind Preparation for the Treatment of Oral Mucositis

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[Objective]

Oral mucositis is a factor that diminishes patients' quality of life (QOL). However, current treatments for oral mucositis face challenges, including poor retention of active ingredients and discomfort during intraoral application. Various water-soluble polymers are used in formulations applied to the oral cavity. Additionally, plant-derived components with antimicrobial activity are gaining attention as potential ingredients to prevent the onset and promote healing of oral mucositis. Therefore, this study focused on xyloglucan (Xylo), which gels upon the addition of polyols. Hydrogels and xyloglucan films were prepared by mixing Xylo with epigallocatechin gallate (EGCG), which has antioxidant and antibacterial properties, and their physicochemical properties were evaluated.

[Methods]

Hydrogels were prepared by mixing a Xylo solution (1.5 w/w%) with EGCG solutions at various concentrations (0.1, 0.25, 0.5, 0.75, 1.0, and 2.0 w/w%), then dispensing the mixture and storing it at 4°C for 24 hours. The hydrogels were then left to stand for an additional 5 days, dried, and formed xerogel films. The tensile strength of the hydrogels, along with the adhesion and water absorption of the xerogels, were evaluated. Additionally, ascorbic acid was added to enhance stability, and the results were analyzed.

[Results and Discussion]

As the EGCG content increased, gel transparency decreased. In the tensile strength test, the hydrogel with 2.0% EGCG showed the highest strength and elongation at break. Regarding adhesion, it measured 1.8 N for 0.25% EGCG and 2.0 N for 2.0% EGCG. Although no significant difference was observed with different EGCG concentrations, the adhesion was similar to that of existing formulations. In the water absorption test, the 0.1% EGCG Xylo gel demonstrated a high water absorption rate. These results indicate that adjusting the EGCG content enables control over the film's strength, flexibility, and water absorption. Therefore, EGCG-containing Xylo gel is suitable for use in film formulations designed for treating oral mucositis.

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1118 Effect of Thermoresponsive Xyloglucan on the Retrogradation of Gluten-Free Rice Flour Bread

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Introduction: The bread-making properties of 100% rice flour, used to prepare gluten-free bread, is poor. Heat-responsive xyloglucan (MTG), which exhibits gel-forming properties upon heating, is expected to enhance bread-making properties; however, there are no reports on its use in rice flour bread. Therefore, this study investigated the effects of adding various thickening polysaccharides, including MTG, on the dough properties,

bread-making properties, staling characteristics, and sensory acceptability of gluten-free rice flour bread.

Methods: Rice flour bread was prepared by adding MTG, tamarind gum (TG), and xanthan gum (XT) at a 1.0% ratio to rice flour, along with additional ingredients including dry yeast, granulated sugar, salt, and olive oil. It was then baked in a 200°C oven for 14 minutes. Rice flour steamed bread was prepared by substituting baking powder with dry yeast in the rice flour bread ingredients and microwaving at 600 W for 7 minutes. These breads were stored for 48 hours at 25°C and 65% relative humidity to examine the changes in physical properties and staling characteristics arising from storage. Sensory evaluation was also conducted to assess acceptability.

Results: The flow characteristics of the rice flour dough showed dilatancy similar to the control and MTG-added samples, indicating that the dough reflected the properties of starch. The specific volume of rice flour bread was significantly lower in the MTG-added sample; however, for steamed rice flour bread, the MTG-added sample was equivalent to the XT-added sample and was larger than that of the control. The apparent elastic modulus and stress at 40% compression of rice flour bread and steamed bread samples containing thickened polysaccharides were lower than those of the control after 3 days of storage. In rice flour bread, the addition of MTG and TG suppressed the hardening effect. Evaluation of the retrogradation of rice flour bread using X-ray diffraction revealed that the relative strength of the control sample was highest on the 3rd day of storage, whereas the MTG-added sample showed the lowest relative strength. In steamed bread, the addition of thickening polysaccharides suppressed retrogradation; however, no difference was observed between the types of thickening polysaccharides used. In the sensory evaluation, MTG-added rice flour bread and steamed bread were rated as softer than the control, even after 2 days of storage. The MTG-added steamed bread was rated as the softest compared to all other samples. These results demonstrate that adding MTG to rice flour bread suppresses bread hardening and retrogradation and enables the preparation of gluten-free rice flour products with excellent baking characteristics and high palatability, particularly when steamed.

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[1134] Hydrolysis-driven restructuring of mealworm protein hydrolysates and their interfacial functionality in emulsion systems.

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INTRODUCTION

Insect proteins have emerged as sustainable functional ingredients, yet native mealworm proteins often exhibit low solubility and limited interfacial activity due to their compact structures. Enzymatic hydrolysis can improve dispersion while modifying structural features relevant to emulsion formation. This study examined how varying degrees of hydrolysis (DH) influence the physicochemical and interfacial properties of mealworm protein hydrolysates (MPHs) and evaluated their effectiveness as natural emulsifiers.

MATERIALS AND METHODS

Mealworm protein solution (1% w/v) were hydrolyzed using Alcalase at 50 °C with 0.5% and 1% (w/w) for 15, 30, and 60 min. The reaction was terminated by heating at 80 °C for 20 min, followed by freeze-drying. SDS-PAGE, FT-IR, circular dichroism (CD), and ANS fluorescence were used to assess peptide fragmentation, secondary structure changes, and surface hydrophobicity. O/W emulsions were prepared with soybean oil, and droplet size, microstructure, and stability were evaluated using DLS, optical microscopy, and Turbiscan analysis. Oxidative stability was assessed by TBARS.

RESULTS

Moderate hydrolysis resulted in clear improvements in colloidal and interfacial behavior.

Particle size decreased from ~360 nm in native MP to ~250–260 nm in hydrolyzed samples, while PDI values remained low (~0.2–0.4). The absolute zeta potential increased (−42 mV → −46 to −49 mV), indicating stronger electrostatic repulsion and reduced aggregation.

Secondary structure analysis showed a clear shift, with α-helix content falling from 26.1% to about 10–12% and both β-sheet and random coil components increasing. These modifications enabled MPHs at moderate DH to form smaller and more uniform emulsion

droplets and improved their resistance to thermal and freeze–thaw stress. Emulsions prepared with these MPHs also showed reduced creaming and lower lipid oxidation than those made with native or extensively hydrolyzed proteins.

DISCUSSION

Overall, the functional performance of MPHs reflected a balance between peptide size, solubility, and interfacial activity. Moderate hydrolysis generated peptides that readily adsorbed to the oil–water interface and formed cohesive interfacial layers, whereas excessive hydrolysis produced fragments too small to stabilize droplets or contribute to network formation, resulting in reduced stability.

KEYWORDS

mealworm protein, enzymatic hydrolysis, interfacial behavior, emulsion stability, insect protein.

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