

Inducing anisotropy in emulsion-filled hydrogels by unidirectional freezing

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Creating fibrous structures in hydrogels is relevant for developing plant-based analogues of meat and fish. A technique that allows to create fibers in a controlled way in hydrogels is freeze texturization. Freeze texturization enables anisotropic structure formation through unidirectional ice crystal growth, producing aligned fiber networks across micro- to millimetre scales. In this study, we systematically investigated the influence of initial gel microstructure and filler addition (liquid: linseed oil; solid: palm fat) on the structural and rheological properties of freeze-texturised hydrogels.

Potato protein gels (10–14% protein) were prepared at pH 6 and 7 (fine-stranded and particulate protein gels) and analyzed for Young's modulus (E_y), fracture strain (ϵ_f), fracture stress (σ_f), water-holding capacity, and mechanical anisotropy. Particulate gels (pH 6) were softer and more brittle, whereas fine-stranded gels (pH 7) showed higher stiffness. Freeze texturization decreased E_y , ϵ_f , and σ_f , but increased mechanical anisotropy, with fiber morphology dependent on protein concentration and initial gel type. Particulate gels formed coarser, larger fibers, while fine-stranded gels yielded finer, more continuous networks. Incorporation of oil or fat droplets increased gel stiffness, firmness, and fiber dimensions.

Overall, we demonstrated that modifying the properties of gels and incorporating fillers enables control over the structure and mechanics of hydrogels formed by freeze texturisation. By subtly varying the gel microstructure, significant differences in fiber morphology could be achieved. These results provide a toolbox that enables the creation of a wide range of fiber types in hydrogels, enhancing our understanding of hydrogel structuring and guiding the development of novel plant-based foods.

Keywords:

Protein gels, Fibres, Anisotropy, Freeze texturization, Texture