

Hybrid cold-set gels from dairy and lupin proteins: linking protein mixing ratio with rheological properties

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The partial substitution of dairy proteins with plant proteins offers a promising route towards innovative and more sustainable food systems (Hinderink et al., 2021). Although combinations of dairy and plant have been widely studied (Lima Nascimento et al., 2023), the effects of blending plant and dairy proteins on the functional properties of hybrid systems remains underexplored. This work aimed to elucidate the impact of incorporating lupin protein isolate (L) into dairy protein solutions, composed of whey (W) and casein (C) proteins, focusing on the microstructure, linear and nonlinear rheological properties of cold-set gels made therefrom. Hybrid protein suspensions were formulated by blending L with W, C, and W:C blends (3W:1C, 2W:2C, 1W:3C), prior to acid-induced gelation with glucono- δ -lactone (GDL).

Gelation kinetics indicated synergistic effects between whey and casein, as 3W:1C and 2W:2C hybrids achieved higher storage moduli ($G' \approx 1.8$ – 2.2 kPa at 1 Hz) than individual ingredients (0.9 and 0.1 kPa in W and C, respectively). Hybrid gels showed enhanced gel strength, with L:W and L:(3W:1C) forming the strongest networks ($G' = 3.1$ and 2.9 kPa at 1 Hz), indicating the reinforcing effect of lupin incorporation. Lissajous-Bowditch figures, obtained from LAOS analysis, revealed that all samples exhibited plastic deformation behaviour, progressively transitioning towards a rectangular shape at strain amplitudes between 627 and 994%. At lower strain levels (25–40%), all gels displayed elongated ellipses with curved edges, and a noticeable inclination of the stress–strain trajectory, indicating that shear stiffening occurred in all samples. Lupin:dairy hybrid gels exhibited narrower curves at low strain and delayed yielding, suggesting improved structural resilience to strain when lupin proteins were added to the gels. The most resistant system was L(3W:1C), that maintained elastic traits up to 627% of strain. To elucidate differences among samples, nonlinear elastic responses, as a function of strain amplitude e , were quantified by calculating the energy dissipation ratio (EDR). EDR results showed that all W:C blends displayed delayed energy dissipation compared to W and C, therefore indicating enhanced structural resistance, while L:W and L(3W:1C), which had the highest G' , showed the earliest EDR increase. Confocal microscopy revealed that W formed a highly compact and homogeneous protein network, whereas C gels exhibited a more open and heterogeneous microstructure, indicative of a weaker and less interconnected matrix. W:C blends had intermediate morphologies, with 3W:1C resembling the continuous structure of W, while 2W:2C and 1W:3C showed coarser networks, more similar to those of C. The incorporation of lupin proteins resulted in more dense and cohesive microstructures in L:W and L(3W:1C), suggesting enhanced protein–protein interactions and network crosslinking, while the gels with a higher concentration of casein exhibited a less continuous network, reflecting reduced structural compactness and connectivity.

These findings demonstrated that combining W:C blends with lupin proteins additionally reinforced the gel network and shifted the energy dissipation to higher values of strain amplitude. Such synergistic interactions highlighted the potential of dairy and plant protein hybrid gels to be tailored through formulation design, enabling the achievement of structures with desired rheological properties, that can be adapted to specific processing requirements or target textural attributes in food applications.

Keywords:

Lupin, dairy, protein, cold-set gel, rheology, microstructure

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