Carrageenan Gels Formed Through Crosslinking with Rapeseed Proteins: Role of Electrostatic and Hydrogen-Bonding Interactions

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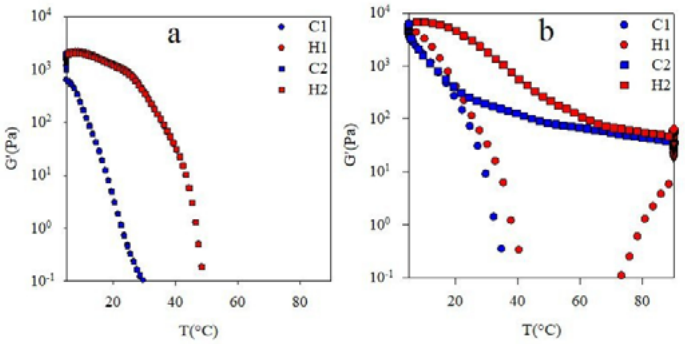
Rapeseed proteins, primarily cruciferin and napin, have attracted attention as sustainable alternatives to animal-derived proteins. We investigated the structure and rheology of aqueous mixtures of κ-carrageenan (κ-car) with cationic napin (nap), anionic cruciferin (cru), and rapeseed protein isolate (RPI), containing both proteins in equal proportions. Mixtures of κ-car with rapeseed proteins formed thermoreversible gels upon cooling, stabilized mainly by hydrogen bonding, without the characteristic coil-to-helix transition of κ-car [1]. Under these conditions, neither κ-car nor the proteins alone formed gels. At higher napin or RPI concentrations, gel formation was hindered by the formation of dense spherical domains arising from electrostatic complexation, which could be prevented by adding salt or increasing the pH toward the proteins' isoelectric point.

Upon heating to 90 °C, κ-car/cru and κ-car/RPI mixtures formed irreversible gels due to protein gelation [2]. Rheological measurements showed that the irreversible protein networks formed at high temperature were further reinforced during cooling by κ-car gelation. The extent of this reinforcement depended strongly on the relative binding affinity between κ-car and the proteins. In contrast, κ-car/nap systems did not gel upon heating but exhibited spherical domains due to coacervation at low napin concentrations (< 5 wt%) that aggregated and sedimented at higher concentrations.

The effects of pH, ionic strength, and component ratios on viscoelastic properties and microstructure before and after heating will be discussed. These results provide new insights into the interplay between coacervation due to complexation and gelation in κ-car–rapeseed protein systems, offering strategies for tailoring plant-based gel textures.

Keywords:
κ-carrageenan, rapeseed proteins, electrostatic complexation, hydrogen bonding, protein gelation



Evolution of G' as a function of temperature for κ-car/napin (a) and κ-car/RPI (b) mixtures during different cooling (C1 and C2) and heating cycles (H1 and H2).

References:

[1] Balakrishnan, G., Moutkane, M., Mudau, C. P. K., Chassenieux, C., & Nicolai, T. (2025). Thermoreversible carrageenan gels formed through crosslinking with napin. *Food Hydrocolloids, 167,* 111439

[2] Mudau, C. P. K., Moutkane, M., Balakrishnan, G., Nicolai, T., & Chassenieux, C. (2025). Heat-induced aggregation and gelation of rapeseed proteins. *Food Hydrocolloids, 166,* 111338