

Tailoring pea protein functionality via high-pressure homogenization for stabilizing and spray-drying hop-enriched O/W emulsions

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Hops are rich in bioactive secondary metabolites with techno-functional potential for food applications. However, their instability during processing and storage requires encapsulation strategies to preserve activity and facilitate their incorporation into formulations. Pea proteins represent a promising plant-based alternative to conventional encapsulating materials, consistent with current sustainability and clean-label trends. Nevertheless, their compact globular structure can limit their interfacial and encapsulation performance. High-pressure homogenization (HPH) has the potential to modulate pea protein structures, but its effect on encapsulation efficiency remains poorly explored.

The aim of the study was to understand how high-pressure homogenization (HPH), applied under different pressure–cycle combinations at constant energy density, can influence the colloidal and encapsulation properties of pea proteins. A hop CO₂ extract was characterized for its total phenolic content (TPC), antioxidant capacity (TEAC), and alfa- and beta- acids composition. Oil-in-water emulsions (20% w/w sunflower oil enriched with 3% w/w hop extract) were prepared with native or HPH-treated pea proteins (6% w/w, 15 MPa × 6 cycles; 22.5 MPa × 4 cycles; 45 MPa × 2 cycles; total equivalent energy applied 90 MJ·m⁻³) and maltodextrin, achieving a final oil-to-solids ratio of 1:3. Emulsions were analyzed for their droplet size distribution, viscosity and colloidal stability, while the resulting spray-dried powders were characterized for physical and chemical stability (e.g. SEM, tap and bulk density, encapsulation efficiency).

HPH significantly affected both structural and colloidal properties. FTIR spectra showed a reduction of lipid-related bands, while a broader O–H stretching band suggested enhanced hydrogen bonding within the matrix. The mean droplet diameter ($D_{[4,3]}$) decreased with HPH intensity. Although hop addition increased the flocculation index (FI%) for emulsion formulated with native proteins, HPH-treated samples, particularly at 22.5 MPa, exhibited reduced flocculation and enhanced emulsion stability, probably due to phenolic–protein interactions. These results demonstrate that, through an optimal pressure-cycle combination, HPH treatment of pea proteins enables their use as a promising wall material for the microencapsulation of hop bioactive compounds, supporting the design of a delivery system for lipophilic hop extracts and their functional compounds.

Keywords:

Pea proteins, high-pressure homogenization, wall material, microencapsulation, hop bioactive compounds