Highly stable aqueous foams with nanocelluloses and pectins

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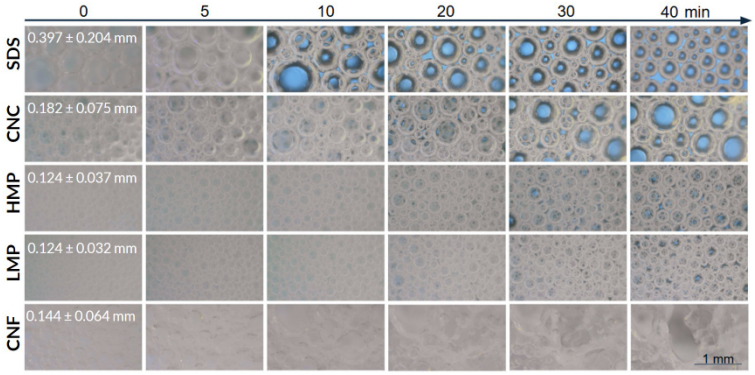
Aqueous foams are dispersions of gas in a liquid phase, widely employed in food, cosmetic, and cleaning applications. Despite being thermodynamically unstable, their lifetimes can be significantly extended by adding colloidal species such as polymers and nanoparticles, which mitigate the effects of drainage, coarsening, and bubble coalescence [1,2]. Foam stabilizers used in industrial formulations are typically derived from petroleum sources or animal proteins, which are associated with environmental problems and allergies. In this study, plant-based biopolymers, including cellulose nanocrystals (CNCs), cellulose nanofibrils (CNFs), and high- and low-methoxyl pectins (HMP and LMP), were incorporated into aqueous foams with 0.5% (m/m) sodium dodecyl sulfate (SDS). Dispersions with varying biopolymer concentrations (0.25–1.5%) were prepared, yielding negatively charged colloidal systems that exhibited pseudoplastic rheological behaviour. Foams were generated by mechanical agitation and evaluated for foamability, bubble size distribution, and half-life (t½). Increasing biopolymer concentration led to reduced foamability and smaller bubble sizes, attributed to higher viscosity and consequently lower air incorporation. At 1.5% biopolymer content, the average bubble diameter decreased from 397 μm for SDS-only systems to 182 μm (CNC), 144 μm (CNF), and 124 μm for both HMP and LMP. Foam stability was enhanced by CNFs and both pectins, with t½ increasing from 3.15 h, in the absence of biopolymers, to 233 h with CNF. In contrast, CNCs did not significantly improve foam stability, indicating that viscosity alone does not govern stabilization. These findings suggest that biopolymers may influence the interfacial organization of SDS molecules and the dynamics of coarsening processes. Moreover, mixtures of biopolymers consistently produced longer foam lifetimes than individual components at equivalent concentrations, evidencing cooperative stabilization effects. Additional cross-linking with calcium ions further improved foam durability across all systems at 1.5% biopolymer content, resulting in mechanically robust cross-linked gels. Overall, this work demonstrates a sustainable strategy for tailoring foam stability using plant-derived colloids, offering for potential application in cosmetics.

Keywords:
Foams, Nanocellulose, Pectin, Foam half-life



Structure of plant-based biopolymer foams over time by optical microscopy.

References:

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