Adhesive Nanoparticles Control Emulsion Properties via Tuneable Interdroplet Linking

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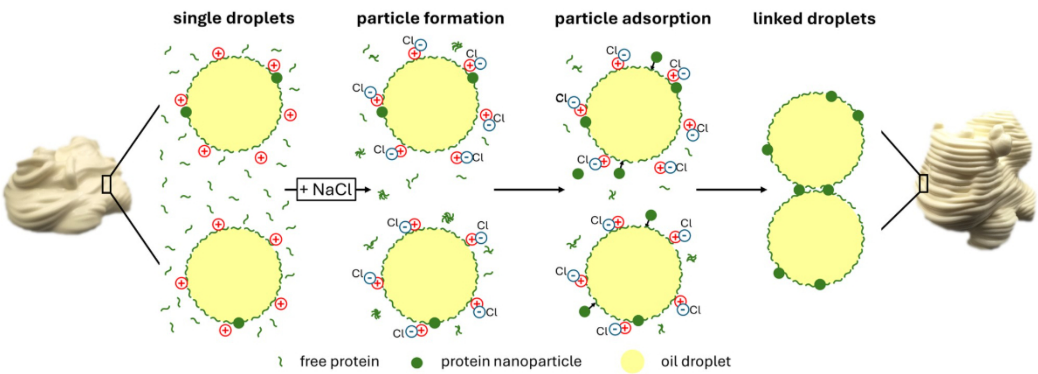
Mechanical properties of emulsions are determined by the resistance of droplets against shear and, thus, interdroplet links are instrumental in providing emulsions with their desired properties. Here, self-assembled pea protein nanoparticles were probed for their attractive intermolecular interactions in forming interdroplet links. The mechanism for interdroplet linking was deduced by studying their adhesive effect across multiple lengthscales: nanoparticles adsorbed on a droplet are able to bridge two droplets, given that the two droplets can come into close enough proximity. The proximity requirement for interdroplet linking is easily met in jammed emulsions, or by reducing the electrostatic repulsion between droplets in dilute emulsions. This mechanism for interdroplet linking was validated with a theoretical model which identified bridging interactions in the thin film as crucial for providing the prerequisite adhesion energy. In practice, raising the ionic strength in jammed emulsions (ϕoil = 0.74) still grants the emulsion with a moderate increase in G′ (1.9 to 4.6 kPa), however, in dilute emulsions (ϕoil = 0.55) interdroplet links transform the emulsion from liquid-like into a 3D-printable solid, increasing the G′ 100-200 fold to 3.2 kPa. Our results demonstrate how promising protein nanoparticles are for tailoring the mechanical properties of emulsions through tuneable interdroplet linking, which opens the door for 3D-printing emulsions with intricate geometrical designs, like in soft microelectronics.

Keywords:
Adhesive Nanoparticles, Tuneable Droplet Linking, Thin Film Dynamics, 3D Printing, Microfluidics, Interfacial Rheology



Graphical abstract illustrating the mechanism for ion-driven interdroplet linking by protein nanoparticles and its effect on the mechanical strength of the emulsion.