

Tuning the Mechanical Properties of Emulsions with Adhesive Protein Nanoparticles

Gijs D. Konings^{a,b}, Ketan Ganar^{a,c}, Emmanouil Chatzigiannakis^{c,d}, Elke Scholten^b, Constantinos V. Nikiforidis^a

*a: Laboratory of Biobased Chemistry and Technology, Wageningen University, Wageningen, the Netherlands,
b: Laboratory of Physics and Physical Chemistry of Foods, Wageningen University, Wageningen, the Netherlands,
c: Processing and Performance Group, Eindhoven University of Technology, Eindhoven, the Netherlands,
d: Institute of Complex Molecular Systems, Eindhoven University of Technology, Eindhoven, the Netherlands,*

gijs.konings@wur.nl

Emulsions are used for a wide range of products including cosmetics, pharmaceuticals, and food, each with their own mechanical requirements [1]. For instance, sunscreen should flow out of a bottle when squeezed but not drip off your skin. To thicken emulsions, one can reduce the mobility of emulsion droplets by increasing the droplet volume fraction or increasing the viscosity of the continuous phase [2]. However, not only the thickness is important, but also other rheological properties, such as yield stress, to provide enough solid-like properties in rest, while yielding at higher shear rates. To accommodate this, the attractive interactions between emulsion droplets might be increased using adhesive particles that link droplets under the right conditions. Such adhesive particles can be made by rapid acidification. When such particles are introduced, they can enhance the mechanical strength of emulsions by >100-fold (from a G' of 18.5 to 3159), providing enough stability to be suitable for 3D printing. On-chip microfluidic experiments revealed irreversible droplet-linking only occurred upon increasing ionic strength, i.e. screening surface charges, showing that electrostatic repulsions hindered the nanoparticle adhesivity. To explain this, we zoomed in on a single interface, where interfaces with nanoparticles became more elastic upon increasing ionic strength, likely through lateral interactions with other components via hydrophobic and van der Waals forces. Using a thin film balance, we validated these findings by measuring distinct adhesion between two interfaces with nanoparticles and no adhesion for interfaces without nanoparticles. Our results demonstrate how the mechanical properties of emulsions with protein nanoparticles can be tuned via ionic strength, highlighting the potential of protein nanoparticles in formulating stimuli-responsive emulsions.

Keywords:

Nanoparticles, Adhesion, Thin Film Balance, 3D Printing, Emulsions, Microfluidics

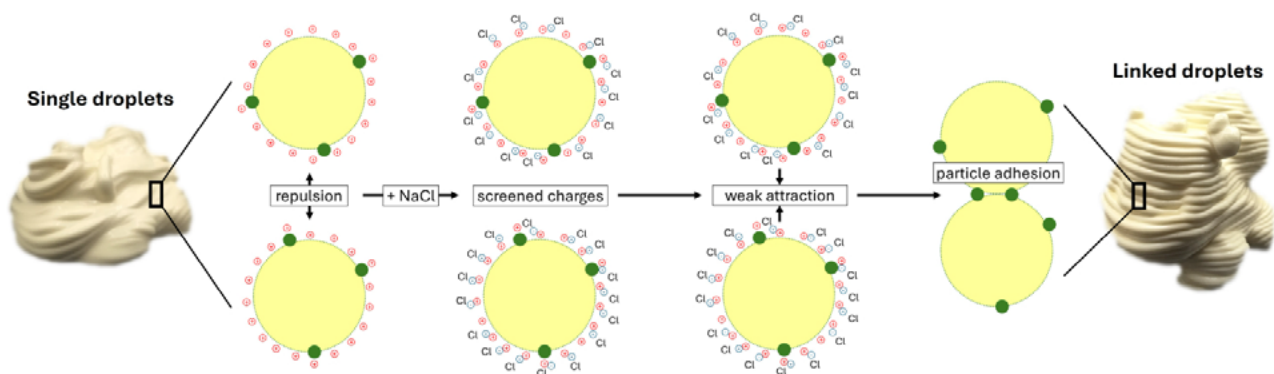


Figure 1: Graphical abstract highlighting the proposed mechanism for particle mediated linking of emulsion droplets and its effect on the mechanical properties of emulsions.

References:

- [1] Cantat, I., et al., *Foams: Structure and Dynamics*. 2013: OUP Oxford. 278.
[2] Cohen-Addad, S. and R. Höhler, *Rheology of foams and highly concentrated emulsions*. *Current Opinion in Colloid & Interface Science*, 2014. **19** (6): p. 536-548.