IFPRI Project Abstract

Accelerated acoustic prediction of aging and failure

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Project Objective:

Low-energy acoustic waves are used to non-destructively accelerate aging in wet dispersions, providing a faster route to stability prediction than conventional stress tests such as centrifugation or thermal cycling. The mechanistic hypothesis is that pulses of high-frequency ultrasound raise particle activity and collision rates without heating the sample, speeding up destabilization while mimicking the underlying aging mechanisms. Testing of this method involves two academic model systems (a colloidal depletion gel and an oil-in-water nanoemulsion) and industrial formulations from IFPRI members.

Approach:

The colloidal gel system consists of PMMA particles suspended in a slightly density-mismatched solvent. Acoustic stimulation is applied and destabilization is tracked with confocal microscopy. Analysis includes radial distribution functions, contact number distributions, mean-squared displacement, and topological descriptors. For nanoemulsions, polydimethylsiloxane (PDMS) droplets are dispersed in an aqueous SDS/polyethylene glycol diacrylate solvent and treated with 20 kHz acoustic waves between 0.2 to 2 mW. Ostwald ripening, coalescence, and creaming are tracked by dynamic light scattering and optical imaging. Industrial agrochemical and emulsion samples from IFPRI Liaisons are also tested along with the model systems under the same acoustic protocol.

Recent Results:

Y3 work focused on pinpointing the physical mechanisms behind acoustic acceleration in both systems. For the colloidal gel, *in situ* confocal imaging during acoustic excitation showed unidirectional particle drift in dilute suspensions, pointing to acoustic streaming as the dominant transport mode rather than the acoustic radiation pressure. Particle mobility was also elevated in dense suspensions relative to Brownian controls. Acoustically treated gels developed loops and connected domains earlier than naturally aged samples, consistent with acoustic forcing driving localized bond-breaking and reformation within weaker regions of the network. Commercial IFPRI formulations showed the same trend, with phase separation arriving 5-6x more rapidly under acoustic excitation. In the nanoemulsion system, exposure time appear to be more important than frequency or voltage, suggesting systems reach a saturation regime at higher cumulative energy input. In short, we hypothesize that the **acceleration is induced by acoustic streaming effects.**

Next Steps:

The project is up for renewal this year. Upcoming work will focus on the colloidal PMMA gel system and particulate industrial formulations due to promising data. The proposed mechanism of acoustic streaming will be validated using image velocimetry and Schlichting streaming velocities. The relative tunability of the acoustic radiation pressure vs. acoustic streaming will be investigated through varying the acoustic contrast factor of the material and solvent pairing. The material and acceleration limits of acoustic power application will be determined. The acoustic energy density will be varied systematically to quantify its effect on effective diffusion coefficients and local bond dynamics. Results from model systems will be carried over to a wider set of functional IFPRI samples, including suspension concentrates and other emulsion systems.