UNIVERSITY OF DELAWARE

CENTER FOR NEUTRON SCIENCE

UNIVERSITY OF DELAWARE ENGINEERING

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INTERFACIAL PHENOMENA IN ACTION: PROBING MEMBRANE FLUIDITY AND DEVELOPING NANOEMULSIONS FOR PLANT-BASED FOODS

Interfacial rheology plays a crucial role in understanding the mechanical behavior of large-area soft matter systems such as biological membranes or emulsions. However, obtaining confident interfacial rheological data can pose a challenge, as thin mono-molecular layers of amphiphilic molecules, such as phospholipids, result in a very weak mechanical response, often approaching the detection limits of rheometers. Furthermore, non-linear coupling between interfacial and bulk subphase flows adds to the complexity of these experiments. To resolve these challenges, I will present a strategy to construct operating windows for commercial and custom-built interfacial rheometers, including the interfacial needle shear rheometer (ISR), to ensure robust and reproducible measurements.

Following the validation of the ISR, I will present the interfacial rheology of phospholipid monolayers, which serve as a model material for biological membrane leaflets. The phospholipid monolayer phase separates at relevant interfacial pressure and moderate temperatures to form a two-dimensional suspension of solid-like disks in a fluid-like continuous phase. The ISR experiments are accompanied by fluorescence microscopy to measure the extent of the phase separation simultaneously with the monolayer rheology. This phase separation can be used to mimic crowding of the interface. Interestingly, the interfacial viscosity does not diverge upon crowding of the solid-like phase, and the interface remains fluid despite strong crowding conditions. This could be explained by the inherent compressibility of a phase-separated interface.

After evaluating the fundamental role of interfacial rheology in phospholipid monolayers, I will present an application-focused project, where nanoemulsions stabilized by plant proteins undergo thermogelation through interfacial interactions, demonstrating the broader impact of interfacial phenomena in structured systems. I will highlight how the final gel structure can be tuned by high-pressure homogenization during emulsification and co-formulation with methyl-cellulose. These findings not only enhance our understanding of interfacial phenomena but also provide valuable insights for formulating plant-based food analogues with tunable texture and functionality.