Dissipative Particle Dynamics as a Computational Tool to detect the Morphology-Rheology Interplay in Pluronic F68/Water mixtures: A Promising Drug Carrier.

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Pluronics (or poloxamers) have attracted growing interest due to their biocompatibility and tunable self-assembly behavior. Composed of hydrophilic polyethylene oxide (PEO) end blocks and a hydrophobic polypropylene oxide (PPO) center block, Pluronics exhibit thermoresponsive and concentration-dependent phase behavior in aqueous solutions. One particularly interesting system is Pluronic F68, which, at 45 wt% in aqueous solution, displays a unique thermoresponsive transition. At elevated temperatures, it assembles into an ordered supramolecular structure, specifically, a body-centered cubic (BCC) phase, exhibiting solid-like rheological behavior. This transition is especially relevant for drug delivery applications, where stable, responsive nanostructures are essential to control the release profile of pharmaceutical molecules. The ability to tune morphology and viscoelasticity in drug-loaded systems is a key aspect in the design of smart therapeutic materials. By leveraging computational tools such as Dissipative Particle Dynamics (DPD) in conjunction with experiments, a wide range of scenarios can be explored, accelerating the design process. DPD is a coarse-grained, mesoscopic simulation technique capable of accessing the mesoscale, which lies beyond the capability of fully atomistic simulations but is essential to capture microstructure formation and its impact on rheological properties. In this work, we perform DPD simulations to study the effects of temperature and drug incorporation on the system's self-assembly and rheological response. We simulate Pluronic F68 in water, both in the absence and presence of varying amounts of diclofenac sodium. Our simulations effectively capture the temperature-induced liquid-to-solid transition in a 45 wt% Pluronic F68/water mixture. The formation of a BCC phase at elevated temperatures is consistently observed in both DPD simulations and experimental results, confirming the reliability of the model. By integrating simulation and experimental approaches, we achieve a coherent and complementary understanding of the system's structural evolution, namely, the core and shell sizes of the micellar self-assemblies, and its viscoelastic response. This methodology supports the design of smart nanocarriers with tunable release profiles. Overall, we demonstrate that DPD is a powerful computational approach for investigating the interplay between morphology and rheology in Pluronic systems, providing deeper insight into the mechanisms underlying their rheological behavior.

Keywords: *Dissipative Particle Dynamics, Rheology, Pluronics, Self-Assembly, Drug Delivery Systems*