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Rheological and Microstructural Characterization of Concentrated Emulsions Prepared by Fish Gelatin

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Abstract : Concentrated emulsions stabilized by proteins are systems of great importance in food, pharmaceutical and cosmetic products. Controlling emulsion rheology is critical for ensuring desired properties during formation, storage, and consumption of emulsion-based products. Studies on concentrated emulsions have focused on rheology of monodispersed systems. However, emulsions used for industrial applications are polydispersed in nature, and this polydispersity is regarded as an important parameter that also governs the rheology of the concentrated emulsions. Therefore, the objective of this study was to characterize rheological (small and large deformation behaviors) and microstructural properties of concentrated emulsions which were not truly monodispersed as usually encountered in food products such as margarines, mayonnaise, creams, spreads, and etc. The concentrated emulsions were prepared at different concentrations of fish gelatin (0.2, 0.4, 0.8% w/v in the whole emulsion system), oil-water ratio 80-20 (w/w), homogenization speed 10000 rpm, and 25oC. Confocal laser scanning microscopy (CLSM) was used to determine the microstructure of the emulsions. To prepare samples for CLSM analysis, FG solutions were stained by Fluorescein isothiocyanate dye. Emulsion viscosity profiles were determined using shear rate sweeps (0.01 to 100 1/s). The linear viscoelastic regions (LVRs) of the emulsions were determined using strain sweeps (0.01 to 100% strain) for each sample. Frequency sweeps were performed in the LVR (0.1% strain) from 0.6 to 100 rad/s. Large amplitude oscillatory shear (LAOS) testing was conducted by collecting raw waveform data at 0.05, 1, 10, and 100% strain at 4 different frequencies (0.5, 1, 10, and 100 rad/s). All measurements were performed in triplicate at 25oC. The CLSM results revealed that increased fish gelatin concentration resulted in more stable oil-in-water emulsions with homogeneous, finely dispersed oil droplets. Furthermore, the protein concentration had a significant effect on emulsion rheological properties. Apparent viscosity and dynamic moduli at small deformations increased with increasing fish gelatin concentration. These results were related to increased inter-droplet network connections caused by increased fish gelatin adsorption at the surface of oil droplets. Nevertheless, all samples showed shear-thinning and weak gel behaviors over shear rate and frequency sweeps, respectively. Lissajous plots, or plots of stress versus strain, and phase lag values were used to determine nonlinear behavior of the emulsions in LAOS testing. Greater distortion in the elliptical shape of the plots followed by higher phase lag values was observed at large strains and frequencies in all samples, indicating increased nonlinear behavior. Shifts from elastic-dominated to viscous dominated behavior were also observed. These shifts were attributed to damage to the sample microstructure (e.g. gel network disruption), which would lead to viscous-type behaviors such as permanent deformation and flow. Unlike the small deformation results, the LAOS behavior of the concentrated emulsions was not dependent on fish gelatin concentration. Systems with different microstructures showed similar nonlinear viscoelastic behaviors. The results of this study provided valuable information that can be used to incorporate concentrated emulsions in emulsion-based food formulations.

Keywords : concentrated emulsion, fish gelatin, microstructure, rheology
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