

SURFACTANT AND PROTEIN FOAMS : DIFFERENCES IN DRAINAGE AND RHEOLOGY

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Summary We report results on the drainage and rheology of foams made with different surface active compounds : small surfactant molecules, large proteins, and their mixture. Our experimental multi-scale approach provides us information at different length scales in the foam, and allow us to understand the origin of the macroscopic differences. It turns out that surface mobility in the foam channels is important for drainage, whereas the thin film structure is more crucial for rheology.

Aqueous foams are dispersion of gas in a liquid, containing surface active agents stabilizing the dispersion. As often in these dispersed systems, there are many typical length scales, and the global macroscopic behavior results from balances and coupling between effects at different scales. In order to elucidate these coupling, we have started a multi-scale experimental approach where we study how to change the foam macroscopic properties, and then track down within the foam sub-structures what are the microscopic origins of these changes.

Changing the surfactant compounds is one way to change the foam properties, though all the foams look the same by eyes. We have used (1) classical small surfactant (like Sodium Dodecyl Sulfate), (2) large protein molecules (casein) and (3) the mixture of these 2 chemicals. These chemicals provide different mechanical conditions at the surfaces of the bubbles, as well as different thin film structures. Beside the chemical composition affecting the surfaces and the films, we have also change -the gas used (effect on the rate of coarsening) - the initial liquid fraction (effect on the compactness of the bubbles) -the sizes of the bubbles, -and the bulk rheological properties of the liquid itself.

We have focused on drainage and rheology issues, searching for differences in macroscopic properties. We used classical bulk rheology, measuring storage and loss moduli, shear rate-dependent viscosity, and normal forces. Air-liquid interfacial studies were performed to get information on the surface dilatational and shear rheology, as well as adsorption dynamics. Thin film textures, fluidity and thickness were evaluated by video-microscopy on single films on frames. Light scattering techniques (in the multiple scattering regime) were also used, in a static mode, to follow the front displacement in the forced-drainage experiments.

The forced-drainage experiments showed that two well-defined drainage regimes can be found, while varying either bubble size and surface properties. It turns out that a rather simple description of these regimes can be done by including the concept of surface mobility, describing the coupling between flow within the surface and in the bulk of the foam channels (and incorporating the surface shear viscosity).

At low mobility, obtained for the protein foams having a very high surface viscosity, the results show that the main hydrodynamic resistance comes from the foam channels, which surfaces are rigid, and in which the flow is Poiseuille-like. These results are in good quantitative agreement with the foam models. As the mobility is increased, there is a smooth crossover from one drainage regime to another. As this crossover is approached, the hydrodynamics resistance of the channels slowly decreases (corresponding to an increase of the dimensionless permeability). From these data, we can estimate surface shear viscosities of the different solutions and found good agreement with other measurements. Around and above the crossover, the biggest hydrodynamic resistance is no longer the one inside the channels but becomes the one inside the foam nodes (where channels get together by four). This node contribution eventually becomes the predominant one, leading to the second drainage regime. We found that in this regime the dimensionless permeability depends slightly on the surface mobility, and remains quantitatively very closed to the one of the other limit (low mobility). The role of the thin films, in terms of controlling the boundary conditions of the foam channels will be discussed, as well as anomalous results obtained for very small bubbles (smaller in diameter than 0.5mm).

The rheology results also show some differences while changing the surface compounds. It seems that the complex structure of the protein thin films (thick and gelified) have to be taken into account, and that properties at this foam sub-structure are important. These thick gelified protein films provide complementary storage and loss contributions, resulting in more elastic though brittle foams.

We also investigated the homogeneity of shear and the possible occurrence of shear localizations (shear banding). We found some evidences of such shear banding, occurring at low shear rates and being more marked for dry foams.

The case of the mixture of small surfactants and proteins is also very rich, as the resulting foams differ from those made of the two pure compounds. We discuss the results in regard of specific interfacial adsorption competition between small and large molecules. It also seems that the result of such adsorption competition is different within the films and at the channel surfaces (there are relatively less proteins within the films, due to a more stringent local confinement).