Structural analysis of foam formed by polyglycerol-type nonionic surfactants

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Polyglycerol (PG)-type nonionic surfactants have a high hydrophilicity, and their Hydrophile-Lipophile Balance (HLB) can be controlled by varying the degree of polymerization. Therefore, these surfactants have been employed in a wide range of applications. To date, the interfacial properties of PG-type surfactants, such as interfacial adsorption behavior, aggregation behavior, and foam characteristics, have been reported[1,2]. However, few studies have investigated the effect of the degree of polymerization of the PG group on foam properties. In this study, we investigated the foamability and foam stability of polyglyceryl laurate ($C_{11}COOPG_{10}$, Fig. 1) and polyglyceryl lauryl ethers ($C_{12}OPG_4$ and $C_{12}OPG_{20}$) to clarify the effects of the degree of polymerization of the PG group on foam properties.

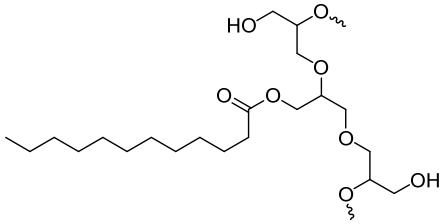

Fig. 1. Representative structure of polyglyceryl laurate.

The foamability and foam stability of PG-type surfactants were evaluated using a dynamic foam analyzer. Physicochemical properties related to foam structure and stability were investigated by measuring interfacial rheology as well as dynamic and equilibrium surface tensions. Small-angle neutron scattering (SANS) measurements of the foam were performed using the SANS-U instrument installed at the JRR-3 research reactor. Scattering profiles were collected every 60 s from immediately after foaming up to 30 min. The time-dependent changes in foam height measured with the dynamic foam analyzer showed that all PG-type nonionic surfactants (0.1 wt%) exhibited high foam stability for approximately 40 min after foam generation, despite being nonionic surfactants. Furthermore, in the long-time region after 40 min, foam stability increased with increasing degree of polymerization of the PG group. Fig. 2 shows the SANS profiles of the foam formed by $C_{12}OPG_{20}$ (0.1 wt%) from immediately after foaming to 30 min. The scattering intensity gradually decreased with time, indicating progressive thinning of the foam films and a reduction in the number of foam films. The foam film thickness estimated from the SANS profiles increased with increasing degree of polymerization. These results suggest that the enhanced foam stability and increased foam film thickness are mainly attributable to the strong steric repulsion provided by the PG groups, together with hydrogen bonding between the PG groups and water molecules as well as intermolecular hydrogen bonding among the PG groups.

References

[1] R. D. Stanimirova, *et al*., J. Colloid Interface Sci. **677**, 250 (2025).

[2] C. Curschellas, *et al*., J. Colloid Interface Sci. **393**, 182 (2013).

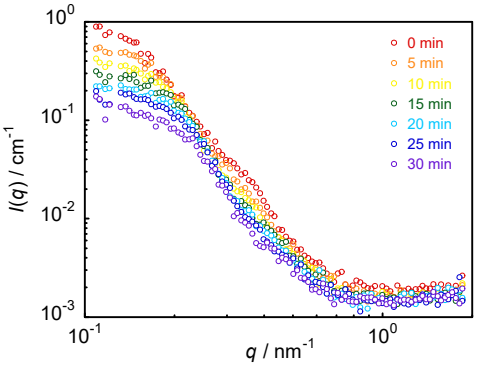

Fig. 2 SANS profile of foams stabilized by polyglycerol-type nonionic surfactants $C_{12}OPG_{20}$ at 0.1 (w/v)% in D_2O.