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Wormlike micelle formation of novel alkyl-tri(ethylene glycol)-glucoside carbohydrate surfactants: Structure–function relationships and rheology

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Abstract

Carbohydrates are appealing non-ionic surfactant head-groups as they are naturally abundant, generally biocompatible and biodegradable, and readily functionalized. Here, seven novel carbohydrate based surfactants (CBS) have been synthesized that contain a tri-ethylene glycol (TEG) linker between a glucose head-group and alkyl tail-group, with linear saturated (C8–18) and unsaturated (C18:1) alkyl chains. The aqueous adsorption and self-assembly of these surfactants was explored using tensiometry and small- and ultra-small-angle neutron scattering (SANS and USANS). With SANS we observed elongation from spherical to cylindrical micelles with increasing alkyl chain length. C16 and C18 chains exhibited pronounced Krafft points, yet formed worm-like micelles as single components upon heating to 43 and 48 °C respectively. The introduction of a mono-unsaturation in the form of a C18:1 chain reduced the Krafft point and gave a surfactant that produced worm-like micelles in water without additives at room temperature. We also observed micellar elongation for C12 and C14 chains at 50 °C due to dehydration of the TEG linker. The room temperature worm-like micelles were further characterized using rheo-SANS and rheology, revealing the C18:1 surfactant to exhibit near ideal Maxwell behavior at low concentrations (2.9 wt.%). These results provide insight into structure-function relationships for CBS, and demonstrate a promising molecular candidate for the formation of viscoelastic worm-like micellar solutions.

Keywords: sugar surfactants, alkyl glucosides, worm-like micelles, small-angle neutron scattering, rheology

1. Introduction

Carbohydrate-based surfactants (CBS) are an important class of amphiphile used in a wide variety of applications, including detergents and other cleaning products, industrial foaming and wetting agents, and emulsifiers in foods and cosmetics.¹ They have gained particular interest because their molecular constituents can be sourced from abundant renewable resources — fatty acids of varying hydrocarbon chain length from the hydrolysis of triglycerides in

vegetable oils (coconut, palm, rapeseed, etc.) plus mono- and oligo-saccharides from the digestion of starchy plants (potato, wheat, corn, etc.) and cellulosic biomass.^{2,3} Typical synthetic routes involve acid-catalyzed glycosylation and trans-glycosylation procedures to produce an acetal linkage between the sugar and the hydroxyl group of a fatty alcohol.^{2,4}

Similar to most other non-ionic surfactants, CBS generally exhibit strong surface activity in water and commonly form spherical micelles which, at higher concentrations, transition into cylindrical micelles that typically increase in length for longer alkyl chains.³ This elongation is the thermodynamically preferred method for reducing interfacial curvature as a means of accommodating the longer alkyl tail-groups.⁵ The transition is rheologically important as an increase in viscosity occurs owing to the steric

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