# Surfactants and Protocols to Induce Spontaneous Emulsification and Enhance Detergency

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**ABSTRACT:** In this study the presence of an oil-soluble nonionic surfactant, Brij 30 (polyoxyethylene-4 lauryl ether), in an oil stain, or its addition to the stain through an oil-based solution or water-based mixture is shown to enhance, to a great extent, the spontaneous removal of the stain from a polyester fabric by inducing rollback and spontaneous emulsification phenomena. These findings lead to potential applications of Brij 30 as laundry pre-spotters for enhancement of the removal of tough stains. The effect of three key factors, namely, the surfactant type, the surfactant concentration, and the surfactant application protocol, on the effectiveness of spontaneous detergency was analyzed *via* ultraviolet-visible spectroscopy. The test fabrics were soiled with a stain composed of mineral oil plus orange OT dye [1-(*o*-tolylazo)-2-naphthol]. The results showed that all three factors were important for effective detergency. Brij 30 removed more than 80% w/w of the stain, whereas sodium dodecyl sulfate removed less than 24% w/w, and Brij 35 (polyoxyethylene-23 lauryl ether) was ineffective, removing less than 1% w/w. It was also observed that a low threshold concentration of Brij 30, approximately 0.2 mM, was required to spontaneously remove the oil stain, and that higher concentrations did not cause a significant enhancement of the effectiveness of soil removal. Brij 30 completed the detergency effect in less than 1 min, which may have beneficial implications regarding reduced energy consumption. Video microscopy studies revealed that at low Brij 30 surfactant concentrations, the mechanism for spontaneous oil removal proceeded predominantly *via* a rollback mechanism and that at higher concentrations, a spontaneous emulsification mechanism became progressively more important.

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**KEY WORDS:** Brij 30, detergency, organic stain removal, rollback, spontaneous emulsification, spontaneous detergency, video microscopy.

Increased economic incentives for energy conservation have stimulated research aiming to develop new surfactant systems and, to a lesser extent, to identify surfactant-application protocols that can reduce the time required to remove soil from fabrics and hard-surface substrates. One of the goals of this research is to identify and induce effective mechanisms of detergency for these applications.

There are at least three principal mechanisms for removal of liquid soils by surfactants (1,2). The first mechanism, rollback, is one in which thin layers of oily soil on the surface to be cleaned retract to form drops in the presence of a strongly wetting surfactant solution. This mechanism depends on the wetting properties of aqueous surfactant solutions. The drops either detach spontaneously, if the surfactant solution spreads over the entire surface, or are broken off by the agitation that occurs during the ensuing washing process.

The second mechanism of relevance is solubilization, in which the oil partitions into the core of the surfactant micelles or into a more easily removable intermediate phase. This mechanism may take place when the soil is a solid or liquid organic material (2,3). The soil can be directly solubilized into the surfactant micelles (4,5); alternatively, the soil may form an intermediate phase containing soil, surfactant, and water that is more readily removed than the original soil, for instance, by direct emulsification. A common intermediate phase involved in this mechanism is a lamellar liquid crystal (6–12). A review by Miller (13) discusses solubilization-emulsification mechanisms and illustrates the formation of microemulsions and lamellar liquid crystalline phases as intermediates (13). There is insufficient information on whether the formation of specific types of intermediate phases is particularly favorable or unfavorable for soil removal.

Finally, a third mechanism of importance is emulsification, in which a thick layer of an oily liquid breaks into drops. This process requires that the emulsion form spontaneously, or that the available agitation be capable of deforming the oil–water interface to the extent that individual drops break off. The existence of low interfacial tension facilitates the breaking off of the individual drops from the interface of the soiled solid substrate (2,3).

Rollback is widely believed to be the dominant mechanism in processes involving the high-temperature washing of cotton fabrics with common anionic detergent formulations. However, soils that are rapidly removed by rollback at high washing temperatures, but that also cause a low viscosity, may require subsequent removal by solubilization at low temperatures. Moreover, rollback is inherently more difficult to

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Abbreviations: Brij 30, polyoxyethylene-4 lauryl ether = $C_{12}H_{25}(OCH_2CH_2)_nOH$, $n \sim 4$; Brij 35, polyoxyethylene-23 lauryl ether; HLB, hydrophilic-lipophilic balance; OT, 1-(*o*-tolylazo)-2-naphthol; SDS, sodium dodecyl sulfate; UV-vis, ultraviolet-visible.