Nanostructured Microemulsions as Alternative Solvents to VOCs in Cleaning Technologies and Vegetable Oil Extraction

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Abstract

Introduction

Volatile organic solvents (VOCs), such as percholoroethylene (perc), hexane, and chloroform, have been widely used as conventional solvents in cleaning technologies and vegetable oil extraction. These organic solvents are classified as hazardous and probable carcinogenic substances. While environmental contamination and health risks occur when using organic solvents in numerous operations, these organic solvents are still used due to their ready availability and a high cleaning efficiency. Therefore, the goal of this research is to find aqueous-based surfactant microemulsions, which can replace VOC solvents with environmentally friendly systems.

Microemulsions contain nano-sized aggregates that can be used as extracting entities at the nanoscale level. This project uses nanoscale microemulsion environments as receptors for oily soils. Microemulsions play a key role in solvent replacement because of the ultra low interfacial tension (IFT) and ultra high solubilization properties of these systems. In this project, we focus on textile cleaning process and vegetable oil extraction applications.

Aqueous-Based Microemulsion for Textile Cleaning Process

In textile cleaning process, long chain alkanes and highly hydrophobic oils (e.g., hexadecane and motor oil) were studied. Based on the hydrophobic nature of these oils, a special cleaning process, such as dry cleaning, is required to remove hydrophobic oily soils from stained fabrics. However, the solvent emission and energy consumption during dry cleaning operation create environmental concerns. An alternative to dry cleaning is wet cleaning. Wet cleaning uses water and nonpolluting detergents instead of hazardous solvents that can be used with computer-controlled washing and drying machines. Wet cleaning is more environmental friendly than dry cleaning while still maintaining the same cleaning efficiency. Therefore, in this project, we have developed aqueous-based microemulsions for cleaning oily soils with more environmental friendly and apply to wet cleaning technology thereby replacing volatile organic solvents for textile cleaning application.

First of all, we formulated microemulsion with target oils (hexadecane and motor oil). We hypothesized that the ultra low IFT and ultra high solubilization properties of middle phase microemulsion will provide the best solvency for textile cleaning. In addition, we observed that use of hydrophilic/lipophilic linkers improved our formulations. We also observe that the newly produced alkyl propoxylated sulfate surfactants, known as extended surfactants (surfactants with “internal” linkers), have desirable properties for this application. The detergency of an organic solvent system (perc), conventional surfactant (sodium dioctyl sulfosuccinate, Aerosol-OT) with and without linkers, extended surfactant, and commercial detergent were compared as shown in Figure 1.

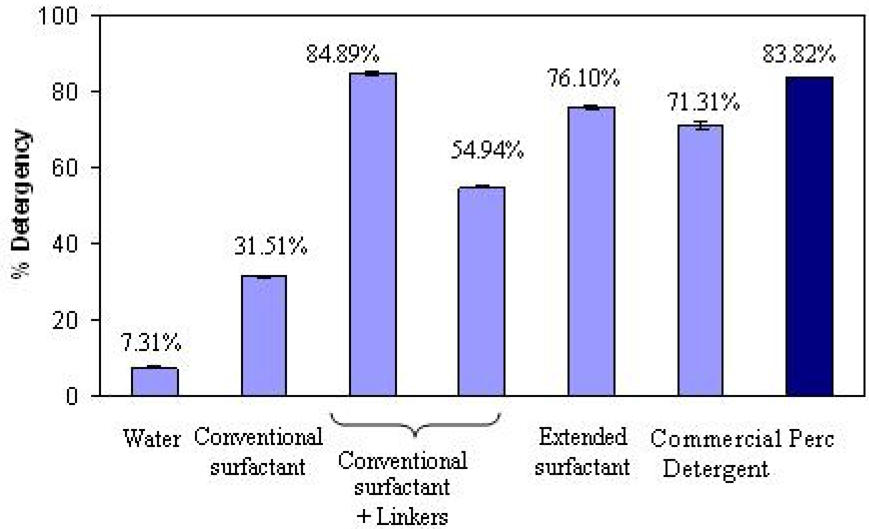

Figure 1. Detergency Performance of Different Pretreatment System

Our results showed that motor oil stains are not easily removed by a conventional surfactant (31.51 percent oil removal). However, as a pretreatment system, linker-based and extended surfactant-based microemulsion can remove at least 50 percent to 85 percent of motor oil stain from 65/35 polyester/cotton-type fabric. In addition, the use of extended surfactant show a synergism in formulating less complex of surfactant formulations while still showing high detergency performance. Furthermore, the removal efficiency of hexadecane and motor oil from textiles, using our aqueous-based microemulsion formulations, is higher than using conventional pretreatment organic solvent and commercial cleaner systems (84.89 percent versus 83.82 percent). The results to date are very encouraging for using surfactant-based microemulsions as organic solvent replacements.

Aqueous Extended-Surfactant-Based Method for Edible Oil Extraction

Edible oils are obtained from oilseed by either hexane extraction or the combination of mechanical pressing and hexane extraction. In 2001, the U.S. Environmental Protection Agency promulgated regulations on hexane emission due to growing environmental concern. The goal of our project is to formulate environmentally friendly surfactant-based formulations that maintain the simplicity of operation and reduces energy consumption while maintaining performance. For a surfactant system to be used in vegetable oil extraction, ultralow interfacial tension is the most desirable property since it promotes both roll-up and snap-off mechanisms of the oil from the seed. A number of conventional surfactant systems have been evaluated but could not achieve low IFT at ambient temperature and without the addition of co-oils and/or alcohols. The newly produced extended-surfactants, with hydrophobic and hydrophilic "linkers" inserted between the head and tail parts of a surfactant molecule, have been able to achieve ultralow interfacial tension with a wide range of edible oils. To our knowledge, we are the first to achieve this result, which shows great promise for use in edible oil extraction. Figure 2 shows the IFT results of the conventional surfactant Aerosol-OT versus the extended-surfactant C12-14PO-2EOSO$_4$Na with canola oil, and IFTs of C12-14PO-2EOSO$_4$Na with various types of vegetable oils; namely canola, soybean, corn and peanut oil.

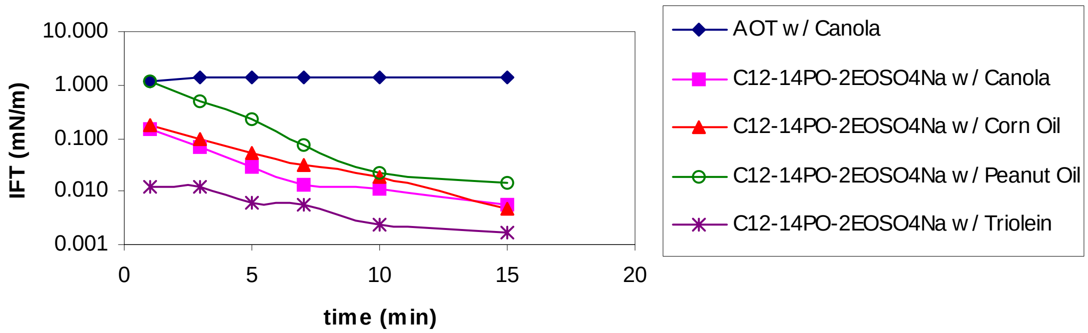

Figure 2. IFT Measurement of Conventional Surfactant and Extended-Surfactant With Vegetable Oils

Figure 3 shows the results of oil extracted by using our aqueous extended-surfactant-based formulation versus aqueous enzymatic (1) and hexane methods. At low concentrations, ambient temperature and no additives, extended-surfactant systems show 90 percent of oil yield, which is very competitive with hexane-based and aqueous enzymatic methods.

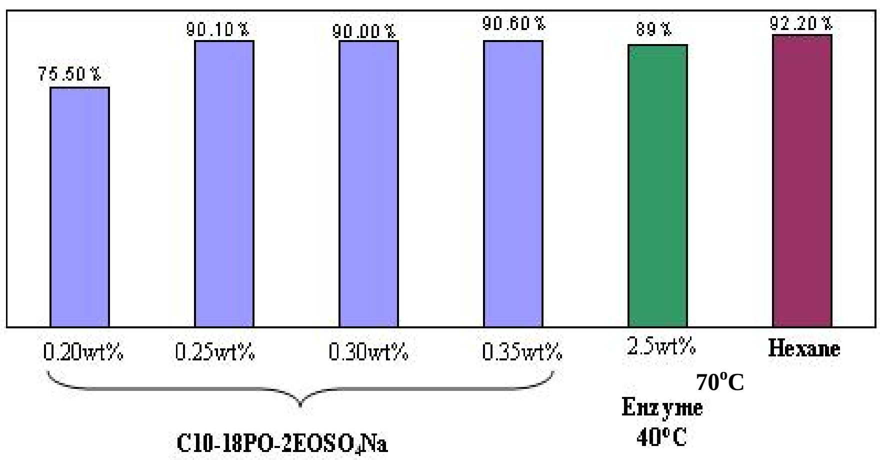

Figure 3. Percentage of Peanut Oil Extracted

In addition, extended-surfactants are able to produce ultralow IFT with a wide range of edible oils; therefore, it is expected these techniques can be used as a universal method such like hexane.

Reference

1. Sharma, Khare SK, Gupta MN. Enzyme-assisted aqueous extraction of peanut oil. JAOCS; 2002: Vol. 79, No 3, p. 215-8.