EFFECT OF VARYING NONWOVEN COTTON SUBSTRATE AND THE PROPERTIES OF THE SURFACTANT SOLUTION UPON THE ADSORPTION OF AQUEOUS SOLUTIONS OF ALKYL-DIMETHYL-BENZYL-AMMONIUM CHLORIDE

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Abstract

The adsorption of alkyl-dimethyl-benzyl-ammonium chloride (ADBAC), a cationic surfactant commonly employed as an antimicrobial agent, on greige and bleached nonwoven cotton fabrics was investigated at varying surfactant concentrations using UV/vis spectroscopy. Results show greige cotton nonwovens adsorb roughly three times the ADBAC in aqueous solution than bleached cotton. At a constant ADBAC concentration of 0.625 g/L, the rate of surfactant adsorption approached equilibrium after 35 minutes in all fabrics studied. The adsorption of ADBAC on cotton nonwovens can be control by varying the chemical and physical properties of the surfactant solutions. Initial research shows that varying the liquor ratio, pH, temperature, and the concentration of electrolyte in the solution affects ADBAC adsorption. Adsorption of ADBAC on cotton fabrics can be attributed to a combination of bulk entrapment, dispersion forces, hydrophobic and electrostatic interactions. Polyester fiber was blended with greige and bleached cotton fibers to further elucidate the adsorption of ADBAC. A linear decrease in the amount of surfactant exhausted was observed as the amount of polyester added to the blend was increased. This indicates that the adsorption of ADBAC on cotton fabrics is primarily an effect of surface interactions of the cotton fiber with the surfactant molecules rather than absorption via bulk entrapment. The resulting data is expected to aid in the development new cotton nonwoven products, such as disposable antimicrobial cotton based wipes, and new surfactant formulations designed specifically for cotton.

Introduction

Surfactants are widely used amphipathic molecules, meaning they contain polar head groups and non polar tail groups, and are commonly classified via the net charge of their hydrophilic head group as either ionic or nonionic. The key feature of surfactants is their ability to adsorb at the bulk solution/solid interface in an oriented fashion, ultimately altering the surface properties of the solid. In textile processing, specifically the processing of cotton goods, surfactants are commonly used to enhance wettability, fabric softness, and dye adsorption. Additional uses of surfactants in cotton processing include stabilization of dispersions for chemical treatments, imparting antimicrobial properties, and removing foreign matter and waxes from the finished fabric. Although there has been a significant amount of research in the area of surfactant adsorption on cellulose by Paria, Kim, Penfold, and other researchers, a limited number of these studies focused on cotton as the form of cellulose and those that have examined the adsorption of nonionic compounds on woven cotton fabrics that has undergone significant processing. The objective of this research is to generate information and improve the general understanding of the adsorption of cationic surfactants onto cotton nonwovens with varying surface characteristics. Specifically, this work will examine the adsorption of alkyl-dimethyl-benzyl-ammonium chloride (ADBAC), a cationic surfactant known to have antimicrobial properties, onto low-weight hydrophobic (unscoured/unbleached) and hydrophilic (scoured/bleached) cotton nonwoven fabrics using the depletion method. The resulting data is expected to aid in the development new cotton nonwoven products, such as disposable antimicrobial cotton based wipes, and new surfactant formulations specifically designed for use on cotton fabrics.

Methods

To produce the cotton nonwovens used in this study, cotton was formed into a web using a tandem card and lightly pre-needled prior to being hydroentangled at 5 m/min using a pre-wet pressure of 35 bar (one jet head) and a bonding pressure of 100 bar (one jet head per surface). The resulting cotton nonwoven fabric was found to be hydrophobic and had an average weight of 50 g/m^2. A portion of the nonwoven fabric was scoured and bleached in a two-step process on state-of-the-art Mathis wet processing equipment using a formulation of sodium hydroxide (scouring) and hydrogen peroxide (bleaching).

Alkyl-dimethyl-benzyl-ammonium chloride was obtained via Aldrich as an aqueous solution containing ADBAC at a 50% concentration in water. The nonwoven cotton fabrics were immersed into surfactant solutions with concentrations ranging from 0.125 g/L to7.5 g/L ADBAC at a constant temperature of 25°C and liquor ratio of 1 gram cotton for every 20 grams of solution. To further investigate the adsorption of ADBAC on cotton nonwovens, the effect of varying the liquor ratio, pH, temperature, and electrolyte concentration of the surfactant solutions were examined. The concentration of ADBAC in the bulk solution at a given time was determined by comparing the absorbance via UV spectra (Varian-Cary model 50UV) of the solution at the end of each experimental run with that of a standard solution. The percentage of ADBAC exhausted from the bulk solution, and thus absorbed onto the cotton nonwoven fabric, was calculated by Equation 1,

$$\%E = \left(\frac{A_0 - A_t}{A_0}\right) \times 100 \qquad (1)$$

where $\%E$ is the percentage exhaustion of ADBAC at time t, A_0 is the absorbance of the ADBAC solutions at the beginning, and A_t the absorbance of the ADBAC solution at time t.

Results

When placed in neutral aqueous solutions, cotton exhibits a negative electric surface charge, thus the nonwovens in this study are expected to readily adsorb the positively charged ADBAC molecules from the bulk cationic surfactant solution. Figure 1 shows the percentage of ADBAC exhausted from the bath onto the scoured/bleached and untreated fabrics as a function of time at a constant surfactant concentration of 0.625 g/L ADBAC. The amount of ADBAC exhausted from the bath exhibits a rapid increase with time for each of the cotton nonwoven samples; however, the slope the data changes drastically after 25 minutes. As illustrated by Figure 1, the majority of the ADBAC is adsorbed onto the cotton fabrics within the first 20 minutes and an equilibrium point, where the surface of the cotton nonwovens becomes saturated with surfactant, is reached shortly thereafter. Interestingly, both the rate and the total amount of ADBAC exhausted from the bulk solution are significantly greater for greige cotton than scoured/bleached. The differences in the total amount of ADBAC adsorbed by the different cotton substrates may be attributed to variations in the orientation of the surfactant onto the surface of the cotton.

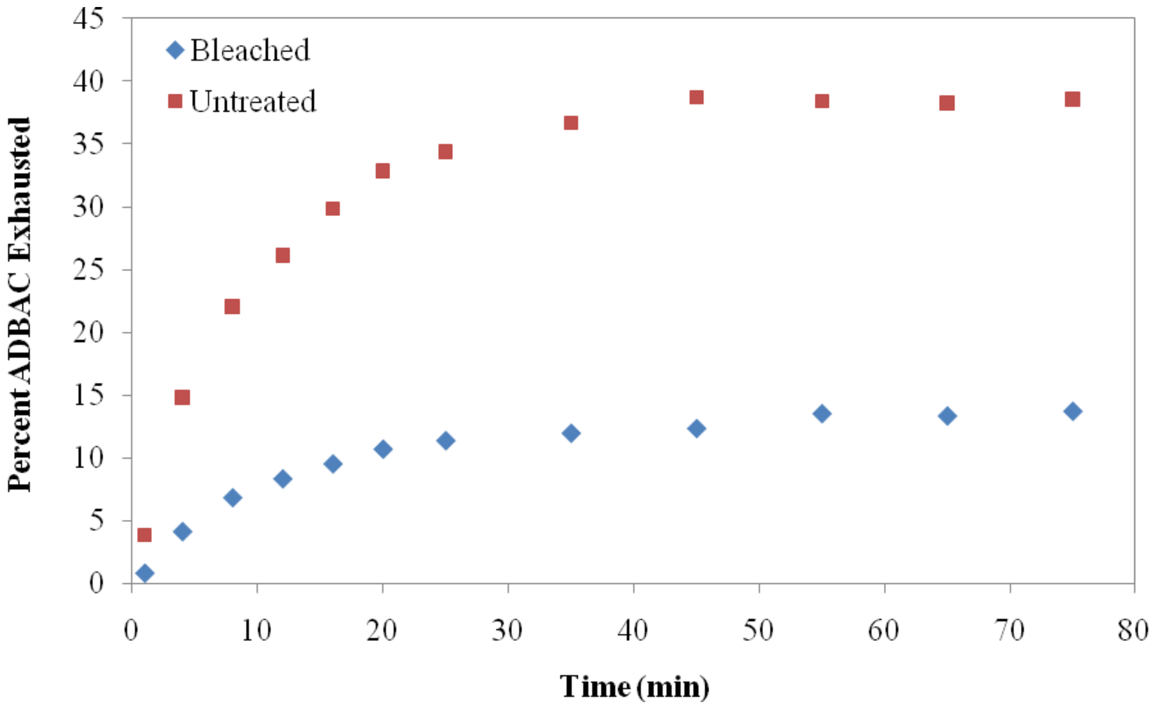

Figure 1: Percent of ADBAC exhausted from the bath as a function of time for (♦) scoured/bleached and (■) untreated cotton nonwoven fabrics.

To further investigate the adsorption of ADBAC on the substrates and to better understand the orientation of the surfactant on the surface, the concentration of surfactant in the bath was varied from 0.125 g/L to 7.5 g/L and the grams of surfactant exhausted from the bath per gram of nonwoven substrate is shown in Figure 2. It can be seen that increasing the initial concentration of ADBAC in the bath raises the amount of surfactant adsorbed per gram cotton substrate gradually in each of the nonwoven samples; however, in all three cases, that amount reaches a plateau around 1.25 g/L ADBAC. The point at which the solid phase surfactant concentration value reaches a plateau corresponds to several of the CMC values for ADBAC reported in literature by Martini and Kopecky. Since adsorption of surfactants involves single ions rather than micelles, one would expect these points to correspond. Untreated greige cotton has a natural waxy coating that makes it hydrophobic, and thus is more prone to adsorption via hydrophobic interactions with the non polar surfactant tail than electrostatic interactions with the polar head group. Scouring and bleaching natural cotton removes the wax, making the resulting substrate hydrophilic and more prone to electrostatic interactions with the head group of the surfactant.

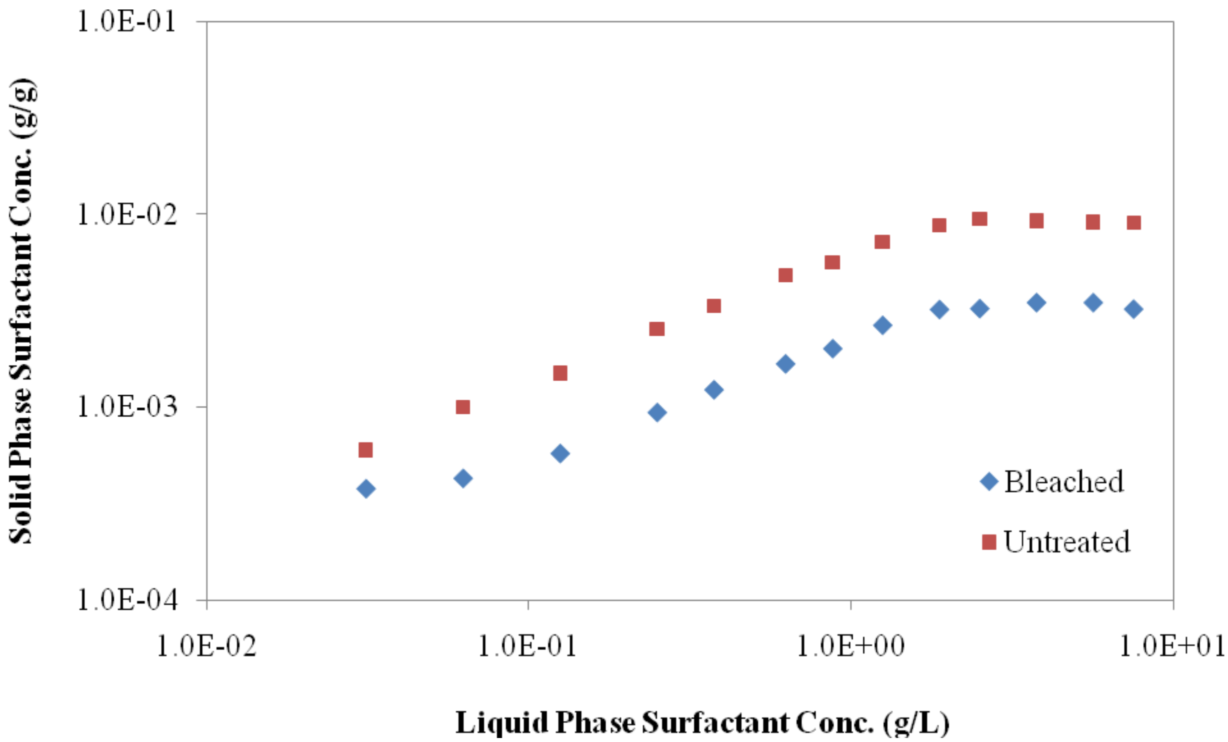

Figure 2: Adsorption isotherms of ADBAC on three different cotton nonwoven substrates at 25°C: (♦) scoured/bleached and (■) untreated.

Since the ultimate goal is to develop a cotton based disposable antimicrobial wipe, the ability to control the adsorption of an antimicrobial agent, such as ADBAC, onto cotton is paramount. One possible way to control the absorption of ADBAC is to alter the chemical property of the surfactant solution with a simple electrolyte. When dissolved in an aqueous solution, added electrolyte will screen the negative surface charge of cotton fabrics. Figure 3 shows the effect of varying weight percent of KCl in aqueous solutions of 0.625 g/L ADBAC on percent of ADBAC exhausted from bath when a cotton fabric was immersed in the solution for 2 hours. Adding an electrolyte decreases the negative potential of the cotton, thus reducing the amount of ADBAC exhausted onto the substrates via electrostatic interactions. Since ADBAC mainly interacts with the waxy coating of the untreated substrates via hydrophobic surface interactions, the effect of electrolyte screening is less pronounced when compared to the scoured/bleached substrate.

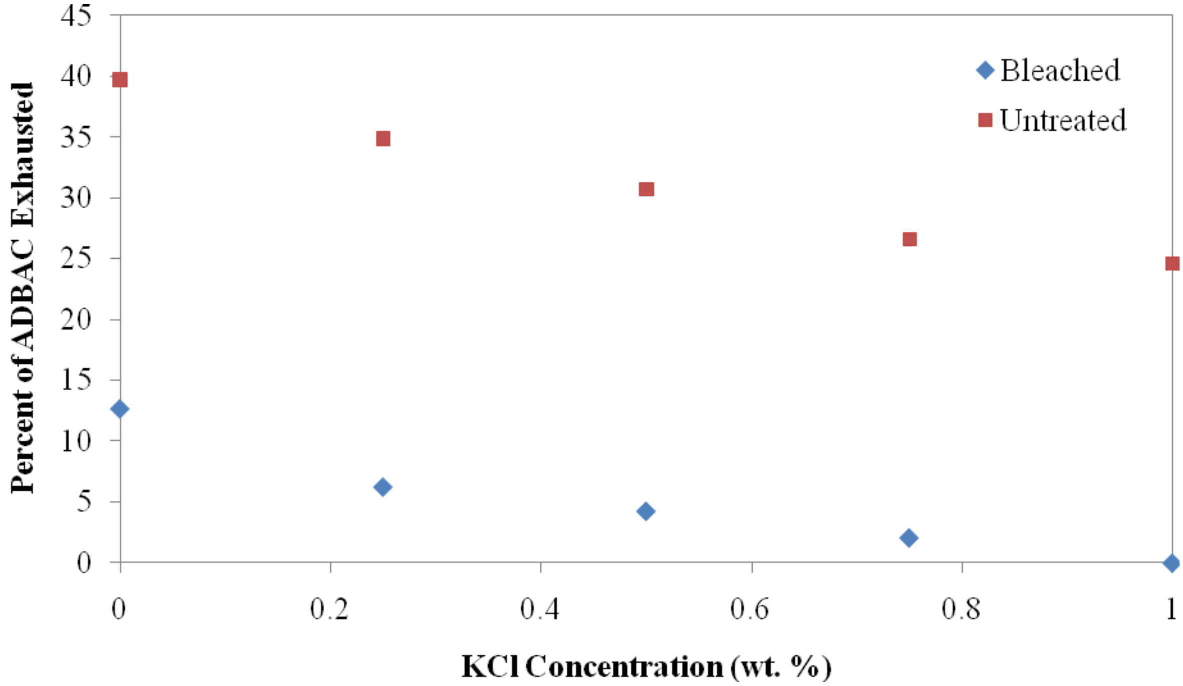

Figure 3: Percent of ADBAC exhausted from the bath at a constant concentration of 0.625 g/L ADBAC as a function of KCl concentration for (♦) scoured/bleached and (■) untreated cotton nonwoven fabrics. Data was collected after the substrate was immersed for 2 hours at 25°C with a pH of 7 and a liquor ratio of 20:1.

Conclusions

The results of this study show greige cotton nonwovens adsorb roughly three times the amount of ADBAC in aqueous solution than bleached cotton. At a constant ADBAC concentration of 0.625 g/L, the rate of surfactant adsorption approached equilibrium after 35 minutes in both untreated and scoured/bleached fabrics. The adsorption of ADBAC on cotton nonwovens can be control by varying the chemical and physical properties of the surfactant solutions. Initial research shows that varying the liquor ratio, pH, temperature, and the concentration of electrolyte in the solution affects ADBAC adsorption.

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